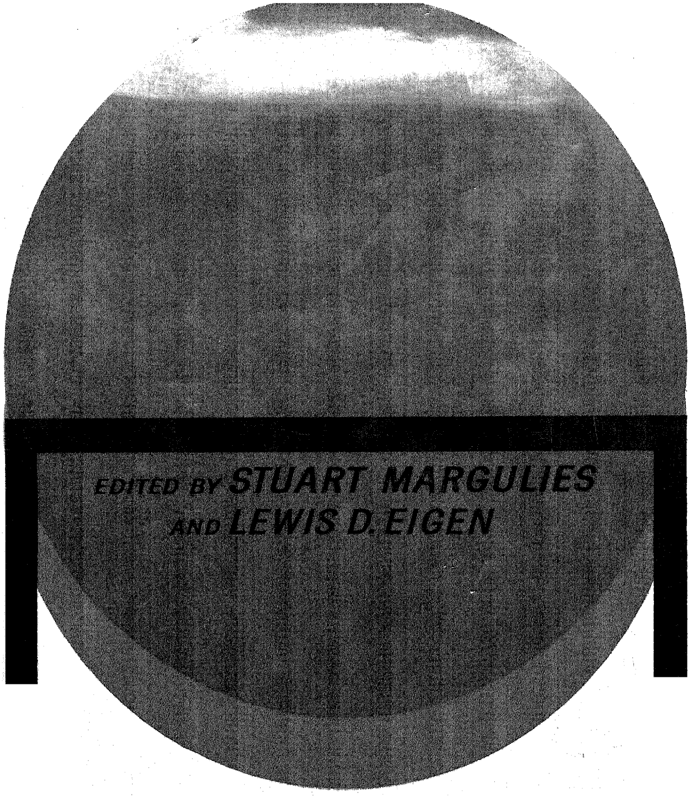

EDITED BY STUART MARGULIES
AND LEWIS D. EIGEN

APPLIED PROGRAMED INSTRUCTION

About the book . .

Two leading figures [illegible] of programed [illegible] gathered vi[illegible] known about [illegible] application and implementation of programed instruction in this one volume. The book discusses the area of application, present and projected economic estimates, utilzation data, student impression data, and almost everything else known from industrial studies. Drawing upon a wealth of empirical data, the contributors offer a penetrating analysis of the role of machines in industrial and military training.

The book deals with the following important practical questions involved in applying programed instruction:

— How much time and money is involved in preparing training programs involving machines?

— Should you use teaching machines or programed books?

— To what sort of situations is programed instruction appropriate?

— Where and how should the programers themselves be trained?

— How much training time will programed instruction require as against training programs employing conventional methods?

With the background provided in this book, the reader will be able to answer these and many other important questions precisely and correctly. The information in this volume is a sound basis for making the necessary policy decisions with regard to the application of programed instruction to specific training or educational situations.

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APPLIED PROGRAMED INSTRUCTION

APPLIED PROGRAMED INSTRUCTION

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Preface

The last few years have witnessed the publication of a large amount of material on programed instruction and teaching machines. Much of this material bears testimony to the increasing maturity of this new art and to the growing sophistication of program writers. The question "Will it work?" has been replaced by the question "How can it be used most efficiently?" and by detailed inquiries into cost, preparation time, available devices, and other utilization data.

This book has been designed to answer these inquiries. Our contributors have, for the most part, chosen not to emphasize theoretical questions but, rather, to focus on practical, implementation data. Descriptions of program users, sources of programs, feasibility of internal production, difficulties of utilization, and economic factors form the central topics of discussion, but the applicability of devices, or even computer-based teaching systems, is also covered in some detail.

In addition to thanking the authors of these articles, we would also like to thank John Annett of Sheffield College and William Barton Marsh of the agency of that name for their lucid analyses of the industrial utilization of programed instruction. We would especially like to thank Bernard Basescu of The Center for Programed Instruction for his helpful comments and invaluable assistance in the preparation of this book. We would also like to express our gratitude to The Center for Programed Instruction for providing us with a home from which we might review the applications of programed instruction.

We really must remark on the unselfish cooperation of our authors. Half of them spell it "programmed." We appreciate their willingness to adopt the spelling with one "m" for the sake of uniformity in this collection.

New York, New York
Februrary, 1962

Stuart Margulies
Lewis D. Eigen

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SECTION 1. Introduction

Most of the articles in this book focus on specific aspects of program construction. They are concerned with detailed accounts of military utilization, with economic appraisals, or with evaluations of available devices. In these articles, the reader generally is expected to have looked at several programs and to be familiar with such terms as ‘‘reinforcement’’ and ‘‘frame.’’

Those seeking a general introduction to programed instruction and those interested in obtaining an overview of this burgeoning new field will find this first section both useful and interesting. Cook and Mechner in their article, and Goldberg in his, provide accounts of the development of interest in this area, describe the characteristics of programed material, and outline the theoretical considerations involved in program construction. They acquaint the reader with the terminology of the field and introduce him to the problems with which later sections are concerned.

The reader who has not yet had the opportunity to examine programed material might find it helpful to read Appendices E through J in conjunction with this section.

Fundamentals of Programed Instruction

By DONALD COOK and FRANCIS MECHNER
Basic Systems, Incorporated

The term "programed instruction" is perhaps the most widely used designation for a new and rapidly developing field that may be described as the application of the science of learning to the tasks of training and educating. The methods of this new field rest on a number of principles of learning that have been widely known but never before brought into simultaneous operation in a systematic way. Research in testing had shown that when tests are scored automatically, learning is improved if students can know their scores immediately after each question. Further, applied research in military and industrial training had paved the way for the use of automatic devices to individualize training.

But the systematic foundations of programed instruction awaited a workable account of learning that could be applied to design in a technology of instruction. Primary credit for this step must go to experimental psychologists and, in particular, to B. F. Skinner of Harvard University. Several decades of study of the learning process under carefully controlled conditions enabled Skinner and his colleagues to establish important principles that apply to all learning. The first of a series of papers describing the practical use of these principles was published in 1954, and, since that date, the field of programed instruction has made rapid strides of great and continuing promise.

At the heart of the method is the conception of human behavior as an orderly process that can be studied and understood in detail by the methods of natural science. Such a conception led to intensive laboratory explorations in the development and maintenance of increasingly complex forms of behavior. It soon became clear that it was possible to design complete "learning environments" in which behavior could be brought to a desired final state through a series of graduated stages. In each stage, the key process is the arrangement of a situation such that the behavior then occurring produces consequences or effects that will bring the learner to the next stage. The design of these stages and effects is at the heart of all approaches to programed instruction.

Intensive research along the lines indicated by Skinner has been widely supported by the United States Air Force and the Office of Naval Research, the Ford and Carnegie Foundations, the United States Office of Education, and other funding agencies. Experimental projects have been carried out in several hundred schools, universities, research institutes, and industrial enterprises, often in collaboration with each other. In case after case, significant gains in learning speed and effectiveness have been achieved by instructional programing. Methods for more effective programing are being discovered and refined, and a number of journals and newsletters have been established that collect, analyze, and disseminate these findings.

THE ELEMENTS OF PROGRAMED INSTRUCTION

The elements combined by instructional programing to produce optimal learning are as follows:

a. Active response by the student.

b. Small steps in which careful control of stimuli produces gradual increments in mastery of the subject.

c. Immediate feedback for each response.

d. Self-pacing, or individualization of the rate at which the learner masters the material.

e. Low error rate for the individual learner, as a consequence of the effective operation of the first four principles.

It can be seen that the above principles incorporate both teaching methods directed at the individual learner and consequences for the administration of instruction to large groups. A program that incorporates these principles requires the learner's active participation at each step. He must carry out an instruction, fill in a blank in a sentence, answer a question, solve a problem, or complete a diagram. As soon as the learner has made the response, the program presents the correct answer. If the response was right, the immediate confirmation reinforces or rewards the response. If the learner was wrong, his error is corrected before he builds new knowledge on a shaky foundation.

In this way, errors and misunderstandings do not accumulate. Each new step the learner takes is small, building naturally on the material just mastered. In a good program, the curriculum is designed in a rational and cumulative manner, with maximum utilization of the inherent organization of the subject. The student is neither held back by slower students nor penalized if he moves slowly through the program. As a consequence he makes very few errors—ideally, none at all.

Active Response

Passive exposure to instructional material does not ensure that the learner responds to it and so incorporates the material into his own behavior. Listening and reading might result from good instruction, but they alone cannot be guaranteed to produce it. Writing, speaking, selecting, and matching, however, involve the learner actively at frequent intervals in accordance with the guiding principle of learning theory that a response must occur before it can be reinforced or rewarded and so become established. To learn is to be able to do, and to understand is to be able to explain.

The response principle is of further importance in that it provides a basis for the evolution of instructional programs. When a record is made of the learner's behavior, the record can be studied to discover where the program is weak, and the program can be revised to eliminate errors.

Small Steps

Material is presented one step at a time so that it can be understood easily. The increment of difficulty between any two steps is typically narrow, so that the total sequence ensures full preparation for more complex and difficult material. Although the final behavior demanded might be quite complex, the learner is confident of his progress at every point.

In the design of an ordered sequence of such steps, the stimulus support for a given response might be strong at first and then gradually withdrawn over a series of steps, with the result that a sophisticated or complex response can finally occur on its own. This result is possible because each frame (the basic unit of instructional material) presents material that is carefully arranged in terms of what the learner knows already: the learner, in mastering such a step, need not refer back to earlier material or look ahead to later material.

Immediate Feedback

When each response gets quick tutorial appraisal, learning is enhanced. Knowing the correct answer rewards the behavior, gives the learner confidence, and encourages retention. This effect, of prime importance in instructional design, psychologists term "reinforcement." It has been shown that, if the circumstances are well-prepared, a single reinforced occurence of behavior can establish that behavior in full strength. Although knowledge of results is the most usual form of reinforcement in programed instruction, other varieties are possible. Advancing to the next frame of the program can be reinforcing in its own right because it indicates mastery of the previous step and an opportunity to enlarge a skill. The number of frames successfully completed can be tallied, with some extrinsic incentive made contingent upon this total.

Self-Pacing

Classroom teaching, whether by conventional lecture or by novel and exciting stimulus media, invariably addresses a hypothetical average student who might, in fact, not exist. The rapid learner is held back, and the slower learner—who might, nonetheless be a good student—is dragged forward too quickly. Few students have a chance to respond in any given session, and the teacher might favor those who are most likely to give gratifying answers. In contrast, programed instruction is learner-centered, and encourages each student to work at his own best rate. Such individualization permits the student to pause for reflection without penalty. Working at a comfortable speed, the learner is, at the same time, given incentives for steady advance through constant reinforcement. The total instructional cycle—increment, question, response, feedback—can take place dozens, or even hundreds or more, times an hour, with teaching and testing blended into one seamless process.

Low Error Rate

Research in instructional programing demonstrates the feasibility of revising programs during their development so that errors produced by learners can be reduced to a minimum. Individual people differ, but if all run into trouble at the same point in a program, a revision of the program is clearly indicated. Revisions always take their departure from frames that generate high rates of error. But it is not necessarily those frames that are revised because an error at a given frame might indicate a weakness earlier in the program. The process of revision almost always lengthens a program. Even a single such revision might not only cut the error rate in half but might increase the speed at which the revised (and longer) program is completed.

Research on revising programs represents a significant advance in learning theory, and indicate that it is possible to learn to avoid errors without actually having to make them. "Bright" students characteristically make few errors with no loss in their capacity to learn. Error-free learning is not only simpler, but its effects improve morale, motivation and retention.

Errors in learning may be likened to the cost of a product. Programed instruction, as a method, produces the product—learning—at a lower cost than has heretofore been possible. Naturally, measured learning achievement—the profit derived from the product—remains the final arbiter. Precautions, therefore, are necessary to guard against poorly-prepared programs that produce few errors but do not assure much real learning. A good program will be mastered with a low error rate, but a low rate of errors does not automatically signify a good program. The program also must teach the material.

THE DEVELOPMENT OF INSTRUCTIONAL PROGRAMS

An instructional program is a sequence of items (often called "frames") throughout which the above principles are applied. A successful program "shapes" the student toward the desired knowledge or skill by requiring him to complete a series of questions of gradually increasing complexity. At the beginning of the program the student makes simple responses to simple questions. As the program advances the required level of behavior gradually advances until the student is finally giving sophisticated answers to complex questions. These answers might involve large-scale analyses and integration of materials, the writing of short essays, the solution of difficult problems, or the drawing of elaborate diagrams. A program can accomplish this by applying certain principles of verbal learning and the theory of concept formation. The better known techniques for establishing verbal knowledge include cueing, interweaving of principles and examples, fading or vanishing of stimuli, concurrent development of related concepts and, concept formation by induction.

Design of a Program

The first step in planning an instructional program is to specify the knowledge or skill that is to be imparted to the student. This knowledge or skill is called the terminal behavior because it is the behavior the student should possess after he has completed the program. The terminal behavior of a geometry program, for example, might be specified as the ability to score 90% or better on the New York State Regents examination in geometry. In general, the specification of the terminal behavior must refer to an examination (or alternate forms thereof) or to tasks that the trainee must be able to perform as well as to the level of performance to be achieved.

It is important to realize that a course outline is not a specification of terminal knowledge. For example, it is not sufficient in a course in electronics to specify an "understanding of diodes" because it is not clear what kind of knowledge is being specified. Such a specification does not distinguish between the following alternatives:

a. What is a diode?

b. What does a diode do in an electrical circuit?

c. Name four different types of diodes, explain how each one works, draw its characteristics, and explain for what type of application each one is suitable.

The above alternatives represent three vastly different degrees of mastery, and it is vital for the programer to know the precise level required. In short, the behavioral outcome to be produced must be made explicit; a set of representative problems that sample the behavior of the trainee must be analyzed to produce a description of the capabilities that must be generated by the program.

Program Construction

Once the required terminal behavior has been specified, the program can be constructed. In some cases, a detailed outline or flow chart of the program might be required in which the topical and behavioral objectives of the program are set forth in sequence. The actual creation of program frames is accomplished by programers who are specially trained in the necessary behavioral principles. The training of programers is a complex process. It can be greatly enhanced through the tutelage of a teacher already skilled in programing theory, but the experience of testing frames on actual subjects is indispensable.

Close collaboration or cross-disciplinary training between individuals with subject-matter skills and those with programing skills might be required. This can be achieved in several ways, depending on the skills involved. The manner in which frames are prepared depends on the nature of the behavior to be transmitted. Verbal skills, involving paper-and-pencil knowledge, can be programed on a series of index cards, with one frame on each card. Perceptual skills might require considerable art work or other stimulus material. Skills based on eye-hand coordination might preclude reading and, therefore, require an audio input through headphones. Similarly, feedback might come in printed or visual form, it might be spoken from tapes, or it might consist of signal patterns from the apparatus being mastered. In all cases, programs begin relatively simply, assuming only the behavior that members of the subject population will bring to the program; and they end with a series of criterion frames, mastery of which is equivalent to possessing the full range of terminal behavior to be produced by the program.

Validation of Programs: Testing and Revision

Program validation is an empirical process. While it is being developed, the program is repeatedly tested on typical members of the subject population who take examinations on the material they are learning. If errors concentrate too heavily at certain points in the program, the program must be revised. Revisions thus are empirically checked and repeated until the final effect is attained: a reliable production of the terminal behavior as measured by the external criterion test and a satisfactorily low error rate as an internal criterion of good programing. As advances are made in the behavioral principles that underlie programing, the number of revisions required to produce a good program can be expected to decrease. The final test of a program might be a field test in which a group of students who are actual members of the subject population complete the program under field conditions and then take a final examination. Satisfactory performance on this examination constitutes the final validation of the program.

Format of Instructional Programs

The format of a program depends on the nature of the behavior it must generate. A common form of verbal programing is now available in the programed textbook. Resembling a book, the programed text contains pages that present frames and answers in a certain order. In one version, the frames progress vertically down the page with the answers in adjacent columns displaced downwards by one step. In such a format, a slider is often used to mask answers and subsequent frames. Another widespread format presents frames and answers on successive pages so that, after a frame has been answered, the page must be turned to expose the confirming correct answer. The learner works through the entire book by taking the frames at the top level of each page and then returning to the first page and working through the book again at the second level, and so on for anywhere from three to six levels, depending on frame size. This format entails a good deal of page turning but has the advantage that a given frame is not surrounded by neighboring frames in the instructional sequence, and consequent contamination from undesired hints and prompts is avoided.

Format and Pedagogical Problems

In one version of programing, each frame presents a paragraph of instruction that is followed by a multiple choice question. Choice of the correct alternative advances the student to the next frame, but choice of an incorrect alternative sends him to a remedial frame, after which he returns to the main frame and chooses again. Psychologists have been critical of such a format on pedagogical grounds. Selecting an answer is a more passive process than actually constructing it, a fact that might affect the learner's ability to recall the response later.

The basis of the selection might be the elimination of wrong alternatives rather than the strengthening of the correct one. A lucky guess might advance a learner who could well profit from the clarifying material in remedial frames. Studying wrong alternatives that at least must be plausible enough to be worthy of inclusion might tear down the very learning that has just been built up before it has been reinforced. The learner might later remember wrong alternatives he has studied, even though he was fortunate enough to reject them at the time. The use of multiple-choice answers might discourage program designers from testing programs, analyzing errors, and revising programs so that each learner benefits from every step.

Such points, though persuasive, cannot be regarded as settled. Research to date, which has characteristically employed brief programs and has not tested for long-term retention, has not shown the significant differences that would be of importance in lengthy programs. These and other issues can be expected to occupy the talents of research psychologists now being attracted to the field in increasing numbers.

The Instructional Frame

The basic unit of programed instruction is the instructional frame. It presents the increment of instruction and calls for the response from the learner. After this response receives evaluative feedback—typically, presentation of the correct answer—a new frame begins. Thus the cumulative effect of a sequence of instructional cycles depends on the design of a large number of frames in the proper order. The topic of frame design and sequencing is receiving increasing attention as the theory of programing develops. The number of aspects to be considered is as rich as behavior itself, and only a few points will be made here.

The Initial Repertoire. The behavior brought to a program by a learner obviously conditions what can be done within the program. In a paper-and-pencil program, he must be able to read. Less trivially, the nature of the verbal connections existing "within him" is of great importance. A frame such as "If automobile means 'self moving,' then __________ might mean 'self-instruction,' " obviously depends on a repertoire of pre-existing verbal fragments and combination rules. The general knowledge the learner can be assumed to have will affect strongly the use that can be made of examples in building up new principles.

Control of Cueing. Responses must be made for the right reasons. But when first called for, a correct response might be made easy by merely requesting that it be copied, by giving synonyms, by prompting with words having similar roots, by prompting with rhyming sounds, by giving a part of the word, etc. These initial cues are then gradually withdrawn, and the strategy by which this is done, as well as the selection of cueing methods in the first place, is a key aspect of frame design.

Over-cueing. Over-cueing is said to occur when the right response is made too easy, or when it is "given away," with a loss in opportunity to strengthen it correctly. To write "There are nine planets. The Earth is a planet. Therefore it is one of the ___________ planets," over-cues the response in that the blank is filled with exactly the same word as preceded "planets" earlier in the frame. A foreigner knowing no English might fill the blank correctly through a shrewd guess because of the cueing provided by the sequential redundancy. This frame might better name all the planets, then ask for their number. The learner who can count will then construct an active response. Beginning programers are prone to over-cueing, as are most teachers who are anxious to hear some correct answers.

Relevance. It probably is best to include in each frame only the material that is required to construct the answer. This practice helps ensure that the frame will be attended to. The temptation to "sneak in" incidental material results in an over-ambitious program, the effects of which will be uncertain.

Review. Material must be reviewed at appropriate intervals. Unlike the memory drum, the frames of an instructional program are not designed to be taken repeatedly; therefore review must be "seeded in" throughout the frames. To avoid rote review, the examples or context illustrating the point can be varied so that new material is integrated with old. In good programing, such review advances the work of the program.

Panels. A sequence of frames might refer to a separate panel—a single display that the learner uses throughout the sequence. The main function of the panel might be that of auxiliary stimulation, as when the frames ask a series of questions about a map; the panel might serve as reference material, as when the frames teach the learner how to use a table of mathematical functions; or the panel might be an arena for behavior, as when a series of frames instructs in a series of arithmetic steps that are "collected" on the panel so that a new generalization can emerge inductively.

Branching. This term refers, not to an aspect of any single frame, but to options or choices among sequences of frames. Many variations of branching can be used, depending on the problem. "Express stops" can be employed where a student is branched ahead to a later stage of the program if he fills out a diagnostic frame correctly. Branching can lead into remedial routines or into optional enrichment of a subject. Programs have been designed in fast and slow tracks with learners shifting as a function of their error rates on a given track. Still other variations of branching are sure to develop in the future. The design of useful branching strategies designed to accommodate individual differences will be most sound if first consideration always is given to the interaction between the individual learner and the program.

TEACHING MACHINES

The term "teaching machine" is best reserved for devices that house, display, and present instructional programs of the sort defined and described earlier. Thus, the machine not only displays material, it has provisions for suitable responses on the part of the student and provides tutorial feedback. By these criteria, audio-visual aides, as well as simulators and other devices, although they might be machines used in teaching, do not qualify as teaching machines.

General-Purpose Machines

Teaching machines now available that have the capability of presenting instructional programs can be simply described. Such machines are primarily intended for paper-and-pencil programs. They house the program on rolls of paper, flat sheets, or fan-folded sheets. A display aperture exposes each instructional frame, and a second aperture provides a space for the response. Feedback is given when the program is advanced—through actuation of a lever, knob, or button—and the correct answer comes to view. It is probably best that the frame and the learner's answer both remain in view when the feedback is presented. For certain programs that require the building of a new response repertoire (as in drawing), or when teaching young children who cannot verbally encode their own responses, this feature of machines can provide a genuine pedagogical advantage. When frame, response, and correct answer are all in view together, the learner's response can be made to advance under a window to prevent erasure or "cheating."

Teaching machines may or may not score responses and tally errors. At present this attractive degree of automation is possible only with certain machines or with programs in which responses can be selected (rather than constructed) and the choice indicated by pressing a button. With constructed-response programs, the evaluation of the answer and a tally of errors must be left to the student—a requirement that is not unreasonable for older students. The day may come when optical scanning (or its equivalent), together with mechanized semantic analysis to assess fine equivalence of utterances, will make these machines fully automated.

Regardless of the manner in which these technical problems are solved, it appears that a permanent place will be assured the programed textbook. It is cheap, flexible, portable, and does not require a large capital investment. Free from the restrictions of a fixed-size aperture for the answer space, programed texts can accommodate a wide variety of responses. Where answer books are produced separately, the program itself is not consumed and can be reused. For instruction in primarily verbal material with students whose fundamental verbal behavior has already been established, the programed text seems to have many advantages and no defects.

Cheating with the programed textbook format might be a problem with young children or students who do not yet understand that the program is intended to teach rather than test. In such cases, machine presentation often is justified. In the case of older students, the problem can be solved by demonstrating that the program is designed to build behavior, not to test it. The periodic administration of actual examinations is an effective way of conveying this distinction. Together with the intrinsic factor that cheating deprives a student of reinforcements or rewards in mastering a program, the use of tests should eliminate the motivation to cheat while taking a program.

Special-Purpose Machines

Special-purpose devices have been developed that are indispensable for teaching certain skills. Among these skills are audio-manipulative coordination tasks, tasks where speed and motor accuracy are essential, and tasks where the eventual work environment must be simulated. Other machines have been developed for special training in areas such as pre-verbal matching of form and color, matching of rhythmic patterns, etc. In each of these cases, the unique requirements of stimulus presentation and response topography dictate the design of machines with special features.

PROGRAMED INSTRUCTION IN BUSINESS AND INDUSTRY

As the training needs of modern business and industry continue to mount, programed instruction can be expected to play an extraordinarily useful role. The internal training of skilled operators is a classical problem of long standing. The increased instructional effectiveness that programing will bring might well alter the strategic role of selection tests and broaden the base of recruitment to a wider population range. Allocation strategies for already selected men similarly might become more flexible.

In developing training courses, existing training manuals might be helpful in some instances—especially with well-organized technical material that is primarily verbal in nature (electrical wiring and blueprint reading are good examples). In other cases, existing training manuals might have to be scrapped and the terminal-behavior requirements developed from scratch.

The nature of the terminal behavior might well depend on critical features of the post-training work environment—an increasingly important subject in industrial design. The principles of man-machine-system design call for the incorporation of automatic, on-line feedback signals, which serve to motivate, guide, clock, and count aspects of production. Thus, the magnitude of the task assigned to training is reduced. These facts suggest that industrial-training-program planning should emerge as a collaborative effort between industrial and programing enterprises—an effort extending in both directions beyond the training phase *per se.*

In the case of sales training, programed instruction has a special potential in the training of widely dispersed personnel. A good example is that of pharmaceutical detail men who must receive continuous on-the-job training to keep abreast—at a rather technical level—of a continuous flow of new products. The promise of programed instruction in the reduction of travel time, cost, and interruption of sales activities is obviously great.

As new technical products proliferate, business and industry finds itself taking on the job of educating the consumer. He must be trained to utilize complex products if he is going to buy them. In the computer industry, where the consumer must master a new problem-oriented language, plans must be made for instructing consumers in that language before the hardware that will obey the language has been assembled. More prosaically, such firms often face the task of training operators sent by customer companies in the use of equipment that has been purchased. Here the educator exerts almost no control over the qualifications of his students. Clearly, improved instructional methods will be of great help in such situations.

Management itself is not exempt from the impact of the training revolution. Increasing demands are made to keep abreast of new processes and products. Managerial techniques themselves become increasingly complex. Often the operating descriptions of cost-accounting, production-control, and other rationalizing procedures go unread or unused because they are not taught effectively. Management games, simulation training, and other techniques for generating company strategy in an age of minimax and probability themselves pose the need for a "strategy of absorption." As companies diversify, decentralize, and process a rapidly altering set of products and services, the need arises for an informational nervous system—a communication network to maintain the corporate identity that to an increasing degree, does not inhere in any one man or group. Electronic communications now can provide the required annihilation of space and time and the effective storage and processing of data, but the final membrane of the skilled behavior of men remains as a barrier and requires a technology of its own to penetrate.

In view of all these trends, it might well be that management, increasingly aware that its "hard" product is enshrouded in issues that center around the training of men, might bring training policy closer in to the round table of executive decision. Training costs and processes should be brought out from under the dark corners of "overhead," reject rates, and other hidden and obscure budget categories. In this process, programed instruction offers a technique of increased effectiveness that will, at the same time, allow training costs to be rationalized effectively, evaluated accurately, and amortized in a sensible manner. That is the final prospect of this rapidly developing field for industry today.

An Introduction to Programed Instruction

By IRVING A. GOLDBERG
Automated Teaching Systems, Incorporated

This brief question-and-answer article has been prepared to answer the various questions that have been asked about programed instruction and to summarize its underlying principles and characteristics.

Question: *What do the terms "programed instruction" and "teaching machines" mean?*

Answer: The terms "programed instruction" and "teaching machine" refer to a revolutionary new development in educational technology that has been gathering momentum during the past six years. This new development is based on principles of learning theory that derive from modern experimental psychology. Its foundation lies in control over the interaction between the learner and the material to be learned.

Question: *What, briefly, is the history of programed instruction?*

Answer: Although the principles underlying programed instruction can be traced back to ancient Greece and the Socratic method of tutorial education, modern developments may be said to date from the work of Dr. S. L. Pressey at Ohio State University in the early 1920's. In 1926, Dr. Pressey developed a testing device that is considered as the forerunner of present-day efforts in the automation of education. Unfortunately, Dr. Pressey's early work met with little public support.

The new educational technique was virtually forgotten until 1954, when a resurgence of interest was initiated by the work of Prof. B. F. Skinner and his associates in the psychological laboratories of Harvard University. Since then, programed instruction has received broad recognition and support. Numerous educational, military, and industrial organizations have undertaken pilot programs to test the effectiveness of the new method, and various commercial ventures have been directed to the development and marketing of vocational and academic programs of instruction and many types of automatic teaching devices.

Question: *What are the principal characteristics of programed instruction?*

Answer: The instructional material is developed by careful analysis of the behavior to be taught. All information, actions and decisions required for successful performance by the learner are carefully specified.

The subject-matter is broken down into a series of short instructional steps called frames. These are organized in a logical step-by-step sequence that leads the learner from his preprogram behavior to the desired terminal behavior. Each frame provides one or more informational statements or illustrations and incorporates one or more questions to which the learner must make an active (verbal, written, or physical) response. Following his response to each question, the learner is immediately shown the correct response to compare with his own.

The learning session is self-paced by the learner. The presence of a teacher is not required, although, in many instances, it may be desirable.

Question: *What are the psychological principles on which programed instruction is based?*

Answer: Programed instruction is based on the principle of "reinforcement"—providing a reward for desired behavior so that the behavior tends to re-occur. Desired learning is automatically "reinforced" with programed instruction by immediate confirmation of each correct response that the learner makes. The learner's self-awareness of successfully responding is inherently rewarding. Programed instruction structures the learning situation so that the learner is able to progress with minimum errors from one learning step to the next. The learner's knowledge of his capability to progress successfully is another source of reinforcement and, thereby, serves to enhance the effectiveness of the learning process.

Question: *What is the instructional cycle with programed instruction?*

Answer: The cycle of instruction consists of the following steps:

1. The learner reads a small unit of instructional material (an instruction, a fill-in-the-blank question, a multiple-choice question, an essay question, or an incomplete diagram).
2. He makes a response by carrying out the instruction, filling in the blank, making a selection from the multiple choice, answering yes-or-no, or completing the diagram.
3. He is shown the correct answer and advances to the diagram.

Question: *How is a program of instruction presented to the learner?*

Answer: Programs of instruction are most commonly presented to the learner either in book format or in one of several other formats that are appropriate for use with teaching machines. Book-format programs are prepared either in printed-and-bound form, or in the form of mimeographed work sheets. Programs for machine presentation are prepared in film form (for projection) or printed on paper rolls or tapes or sheets (for direct reading). Several very complex machines include the instructional program as an integral part of the device; the presentation and sequence of the program is controlled by changes in the state of electrical circuitry or mechanical components.

The physical arrangement of the instructional material within each program is accomplished in several ways. Typical arrangements present the instructional items in numerical order, with the answer to each question provided beside it or on the following page.

Depending on the particular book-form or machine program that is used, the learner's response can be made directly on the presentation medium itself, on an answer-book or answer-tape that is provided separately from the presentation medium, or by means of input controls provided for response purposes. With book-format programs, a means is usually included for the learner to mask the answer to each question until after he has made his own response. With machine programs, masking of the correct answers is accomplished by the device itself; the exposure of each answer is either automatic immediately after the learner's response or is under the mechanical control of the learner.

Question: *What are the principal characteristics of a teaching machine?*

Answer: Numerous types of teaching machines have been developed. They vary from very simple devices priced at under $5 to very complex devices priced up to as much as $20,000. In general, all types of machines, regardless of price, incorporate the following characteristics:

a. A program of instruction is exposed, one frame at a time, to a learner, who must respond in some way to each frame before the program is advanced to the next one.

b. After each response by the learner, the machine exposes the correct answer.

c. The pace of exposure of the instructional item is controlled by the learner; no teacher need be present.

It is evident that, in general, the teaching machine merely serves as a convenient means for the presentation of programed instruction. As such, the machine itself is of secondary importance to the learning process. But it performs several important functions: it permits automatic control over the exposure of the instructional material and thereby prevents cheating; it eliminates the need for complicated instructions; it provides a simple means for recording and scoring the learner's behavior; and it can aid in maintaining the learner's interest because of its "hardware" characteristics.

Question: *What are the steps involved in the development of an industrial training program with programed instruction?*

Answer: The development of a programed-instruction course for industrial application is accomplished by the following steps:

1. Task Analysis. The programing company undertakes an analysis of the tasks, skills, and procedures that are required for satisfactory job performance. Specific training requirements are defined in consultation with responsible personnel of the client.

2. Content Developments. Subject-matter is developed in terms of a behavioral definition of the component skills and informations that the program must impart to reach the final behavior desired of the learner. The subject-matter is prepared in the form most applicable to the training task. Practice and drill materials are incorporated in the body of the program as required. Where appropriate, instruction and practice in the use of equipment and other job-connected materials are included.

3. Program Editing and Testing. As sections of the program are completed during the content-development process, they are submitted to an editorial and testing process. Content accuracy is carefully checked. The logic and order of the program is evaluated to insure that each instructional item provides the necessary information. Each item is carefully appraised to see that it is based on preceding items and that it prepares the learner for items to follow.

The testing of the program is accomplished empirically. As each section of the program becomes available, it is given to a small sample of the ultimate learner population. The results of this test are carefully evaluated, and content material is modified and restructured as necessary.

On completion of all sections of the program, the final copy is submitted to a final editing and testing process. The complete program is again tested with a representative sample of the user population to validate its utility and effectiveness in terms of the specified training objectives.

Question: *How does programed instruction compare with conventional instruction?*

Answer: The classroom lecture is the principle tool traditionally employed for teaching. Although it affords a highly efficient and economical means of communication between teacher and learner, the lecture has several inherent drawbacks. The relationship between lecturer and learner is basically passive, and most of the learner's responses are covert. The lecture materials are necessarily designed for group use although each learner can respond only in accordance with his individual intelligence, motivation, and attention. The provision of stimulus situations that set the stage for appropriate responses from the learner is entirely dependent on the skill and intuition of the lecturer who, for the most part, has no means of recognizing or reinforcing the learner's covert behavior.

An attempt is made to correct some of the deficiencies of the lecture by periodic tests that check the adequacy of the learner's behavior. However, even the most efficient tests make no provision for the correction of errors at the most critical time in the learning process—when such errors first occur. Thus, although the testing technique can readily detect errors in learning, the correction of such errors must be achieved subsequently by appropriate re-education. This makes for an inefficient and uneconomical system of education.

Programed instruction overcomes the basic shortcomings of the lecture method. It insures control over the teaching relationship by demanding successful interaction between the learner and the material to be learned. It makes appropriate use of rewards to reinforce corrective responses and, thereby, insures that effective learning occurs. Programed instruction provides the required educational functions of teaching, testing, and corrective instruction (where necessary) automatically and simultaneously. It permits the learner to proceed in terms of his individual capability and time. It frees the instructor to use his time and skills in a more direct relationship with the learner.

Question: *What are the important terms in the field of programed instruction?*

Answer: The important terms in the field of programed instruction are the following:

a. Frame—a single instructional item, including informational material, question, and answer. Frames are, generally speaking, the constituent elements of a program.

b. Linear program—a program in which the sequence of frames is fixed and independent of the learner's responses. The order of presentation of the frames is the same for each learner and does not vary whether or not the correct responses are made. Examples of linear programs are given in Appendices A, E, F, H and I.

c. Branching program—a program in which ancillary informational paths are provided in addition to the main informational sequence. Ancillary paths are selected for presentation in accordance with the learner's response pattern. They are utilized to provide a vehicle for review and for presentation of additional information. Appendix G illustrates a typical Crowder-style branching program.

d. Cue or prompt—aids that are incorporated in some frames to enable the learner to respond correctly. Several different forms of cue or prompt are illustrated by the following frames (taken from a program in Business Mathematics prepared by H. Huffman and S. Margulies):

10. Most employees contribute part of their salary for insurance. The Federal Government provides insurance for an employee in the Fed____ Ins_____Contributions Act. (Complete the words)	10. Federal Insurance
11. Federal Insurance is financed partly by employees. The Congressional Act establishing this insurance is called the F ______ I_____C_____Act. (Complete the words)	11. Federal Insurance Contributions
12. "Social Security tax" is a common non-technical term for F.I.C.A. tax. What act establishes this tax? _____ _________ _________ _________	12. Federal Insurance Contributions Act

Of the three frames illustrated, frame 10 provides the most extreme example of prompting and 12 the least.

e. Fade or vanish—terms applied to the gradual decrement of cues during a program. As cues and prompts are faded out, response difficulty is increased. The reduction in cueing strength through the three frames illustrated above demonstrates the application of vanishing.

SECTION 2. Internal Industrial Programs

This section is devoted to a consideration of the techniques by which three companies developed programs for their own use. These early projects were aimed at answering the fundamental questions that every company must consider: Is programed instruction truly feasible in industry? Does it result in decreased training time or increased efficiency? Do employees accept it? Do machines play an integral role?

In the first article, the early experiences of Eastman Kodak are summarized. The dearth of commercially available industrial material, the decision to develop programs internally, the selection of program writers, and the initial employee reactions are outlined. Particular attention is given to the general requirements for an efficient machine and the question of whether or not to use a microfilm storage device. Other important problems, such as administrative procedures, preparation time, and the selection of subject-matter areas, are also discussed.

The second article, based on an IBM report, is directed at answering the question: Is programed instruction really worthwhile? The material conventionally taught in 15 classroom hours was organized into a programed textbook, and comparisons were obtained between classroom-trained and program-trained students. Trainees who learned this material through programed textbooks took less time, obtained higher final examination scores, showed greater uniformity of performance, and enjoyed the course more than students exposed to conventional material.

The importance of machine presentation of programed instructional material has been a widely debated issue. The third article is based on a Bell Laboratory study that is important because it was done under industrial conditions using a lengthy program and a machine especially designed for this material.

Results indicate that machines and textbooks work equally well. This report also provides data indicating how many hours a day students can use programs and, also, the average instructional time required for bright and dull students.

Programed Learning and Teaching Machines in Industrial Training

By JEROME P. LYSAUGHT
Eastman Kodak Company

Wherever teachers, educators, and industrial trainers have turned for the past several months, they have been confronted with the evidence and challenges of a new force in learning. Call it automated teaching or programed learning—or what you will—the data demand our attention. From the pages of *Fortune*, *Time*, *Business Week*, the newspapers, the journals, including the journal of the *ASTD*, headlines and commentary cry out for an awakening on our part to the happenings in educational experiments. Already claims are mounting that here in our own time we are witnessing the greatest breakthrough in education since the printing of the first textbook. Because these claims are made seriously—by men of proven ability—they dare not be ignored.

On the other hand, because most of the reports to date have concerned the experience of teachers and students in schools and universities, with little emphasis on experimental developments within business and industry, it may be possible that the applications to the adult level have been minimized or even neglected. For this reason, we feel you may be interested in the experiences of the Eastman Kodak Company in applying these new techniques to their ongoing program of industrial education.

In order to present our information in some form of order, we would like to devote this article to our experiences with developing learning programs and programers. We also would like to trace for you our investigation of the equipment phase of automated teaching—the teaching machine. In a strong sense, this makes for proper emphasis as well as convenience. The primary question, of course, deals with the educational worth of the program—through its use does the student actually learn, effectively, efficiently? The secondary question involves how we wish to present such a program to the individual learner.

The Eastman Kodak Company employs about 47,000 people in the United States and 74,000 world wide. This will give you some understanding of the industrial training potential that we must face. Trends develop in every human activity, and, if there has been any single recognizable trend in training within our company, it has certainly been toward a more and more individualized approach, based on specific, personal needs. There have been a number of reasons for this increased emphasis on individualizing our training efforts, and our evaluations attested to its effectiveness.

Approximately two and a half years ago, we first became acquainted with the theoretical field of programed learning. Because it seemed to offer a means for sharply improving our industrial training methods, and because it seemed uniquely designed to emphasize the individual aspects of application and rate of learning, we were intrigued. Within a few weeks, we had embarked on the research and development of programed learning for industrial applications.

PROGRAMED LEARNING IS NOT NEW

We began, of course, by broadening our acquaintanceship with the published materials in the field. We entered into correspondence with those who were working at the scholastic and collegiate levels. We talked time and again with all those whom we could reach that were actively engaged in programed learning utilization. To our mingled relief and chagrin, one of our earliest discoveries was that programed learning was not the new-born babe we had initially been led to expect. Rather it was the culmination of effort that began at least 35 years ago with Sidney Pressey at Ohio State, and had, in more recent times, been revitalized by the efforts of B. F. Skinner and his associates at the Harvard Psychological Laboratories. From 1955 on, we learned programed learning had been taken under study at a score of colleges and research centers—and even to the classrooms of elementary and secondary schools. While there was hardly anything new under the sun, we wondered how we had contrived to stay so long in the shade.

PROGRAMED-LEARNING THEORY IS UNIQUE

Programed learning, we found, was not to be lumped with—or confused with—the large number of learning techniques and devices which are regularly advanced in the journals. Audiovisual aids, for instance, contribute much to the learning process, but they are inherently stimulus devices, and are not a complete learning system. Programed learning is unique in theory and in practice for it offers the student a complete learning "cycle." Because this was a key understanding we had to get across to our industrial training people, it might be best to describe briefly what is involved in student use of programed learning, and relate it to the widely-accepted stimulus-response learning cycle, so that we can then stand on common ground.

The learning program consists of a carefully constructed pattern of learning bits. After each presentation of information, the student is immediately given an opportunity to answer a question, construct a solution, solve a problem, or in other ways to demonstrate that he has acquired mastery of this bit of learning. As quickly as he responds, he is given the opportunity to compare his answer with the program answer to determine his own effectiveness. All of this takes place between the individual and the program, and is paced by the student himself.

Two alternatives now follow. If the student has made the correct response to the stimulus item, confirmation of his correctness by the program serves as immediate reinforcement. And any classroom teacher knows the satisfaction and reward of a student's learning—and simultaneously knowing that he is learning. On the other hand, if the student has responded incorrectly, he obtains the advantage of immediate knowledge of his error. He need not wait for a later class period or examination paper to recognize a mistake. In psychological terms, we apply immediate extinction to incorrect performance.

This describes what happens as a student responds to a single stimulus item. The learning program for a single term may consist of some 2,500 to 5,000 items. These items are so interconnected and designed that the student will constantly progress to higher degrees of complexity. At the same time the program introduces review and recall items enabling him to retain and master the course material.

In all this, the learning program is designed to be self-contained and self-sufficient so that the student can learn the material through his active interaction with the stimulus items. Many educators feel that with properly programed stimuli the student will not only master the material but do so with almost complete freedom from error since he should always be prepared by previous items to answer correctly the item next placed before him.

THERE ARE FEW INDUSTRIAL PROGRAMS

While our initial efforts had unearthed a goodly volume of theoretical knowledge, we found that the actual number of developed learning programs was few. And most of those which were available were essentially non-industrial subjects. That is, while those we met spoke highly of the work Douglas Porter was doing in 6th grade spelling, this did not seem to be a program which we could well anticipate for use within the Eastman Kodak Company. Some of the existent programs did offer more direct application, particularly those designed for college level courses.

It was obvious, however, that if we were to get any real distance run out of programed learning, at least in the foreseeable future, we would certainly have to program many of our own industrial subjects. Other companies looking into the field came to the same conclusion, and this reinforced our desire to make an effort to program.

Our initial venture—with hardy nods to our compatriots from IBM—was to program the interpretation of punchings in standard data cards. There are a number of cards which people handle at Kodak which have various information punched on them—usually on the line where your signature is supposed to go. There being a great deal of natural curiosity about the meaning of these holes, we were assured of inquisitive souls and volunteer students. Additionally such material would have practical application to our training efforts for electronic data programers.

Initial Kodak Efforts

So we began to program. In the main, we had to break our own way for there was very little published material on the techniques of program item construction. We evolved our own principles, and rewrote them as we experienced preliminary student feedback. At the end of several weeks—and the development of 70 frames of a programed course–to our delight, and some amazement, people could actually read the punchings in the data cards.

Having determined that programing for industrial training was possible, we set out to determine its practicality. Many of our areas of training were explored in order to set up some reasonable priorities for programing effort. Necessarily, each of these was to fulfill a bonafide training need since we intended to study cost, effectiveness, and student reaction to the new approach.

It was also evident that we needed to train additional programers. This we began to do. The trainees were chosen to represent not only industrial training people, but also production and staff departments. The training program consisted of an extended workshop with emphasis on the construction of an actual programed sequence. (Incidentally, we now have one man programing how to program.) Not all of our trainees developed into programers, but approximately 75% of our "graduates" have subsequently programed industrial training course material.

Programing Experience

Some of the findings—which must at this point still be quite preliminary—indicate that there is some correlation between intelligence and programing skill, and between knowledge of subject matter and the ability to program that matter. More important than either of these factors, however, is the deep, personal interest of the individual in devoting himself to this work. I am suggesting that a programer must be intelligent, knowledgable, and beyond this, dedicated to producing a new medium which will idealize the learning situation for the student. Fortunately, these people do appear, and they are constantly buoyed up by seeing the results of their efforts reflected in student performance.

We also discovered that the rate of individual programing varied considerably—our results are too fragmentary to suggest why with any great accuracy. On the overall, by the time we add in the time required for evaluation and refinement of the items, and redesign of items to keep us within a 5% error ratio, we find we spend between 30 and 60 minutes per frame of a finished program.

Because programing represents an investment in time and personnel, we have directed our own efforts at producing programed materials in those training areas where we cannot expect an early introduction of commercial programs to the market. Where we know programs are being developed commercially, we are content to wait and evaluate their efforts. In the meantime, we are going forward, emphasizing financial justification, and training mastery.

Evaluation of Early Results

We began some critical evaluative studies of learning results. This effort is being made by a joint team of industrial trainers, industrial psychologists, and programed learning personnel. The reports of the studies will be made available upon their conclusion since we anticipate they will be of importance in judging the importance of programed learning on industrial—and all adult—learning.

The comments of a few of our students might be of interest. They reflect the general tenor of remarks, and have not been chosen to show a particular bias: "I had to give it (the program) my complete attention." "It forces intense concentration." "Felt you were made to stay right on the problem." "It was intriguing." "I think I learned quite a bit although it was all verbal." "I learned something. I was familiar with the subject, but it clarified terms." "Completely dumb on the subject; learned quite a lot."

These are the experimental beginnings, yet they point the way to greater effort. Our programers and our students are convinced that here we have in our hands a new and forceful tool to improve learning. We have already initiated programing in these areas: logarithms, slide rule, basic photography, theory of sensitometry, industrial relations standard procedures, supervisory training, materials handling, and economics. We intend to continue and expand these efforts.

Up to this point I have hardly made mention of the teaching machine, the presentation device of programed learning. Naturally, when we had begun our efforts at programing, we came up against the question of how to present such materials to the student. To answer this, we undertook a concurrent research and development program in teaching machines while we worked on programs and programers.

As we began to train additional programers, and to select initial subject-matter areas, we had to consider the manner in which we would present programed materials within the company.

Sometime before this, we had received from Dr. James Holland a copy of the psychology course which he and Dr. B. F. Skinner had prepared at Harvard.* This course came in the form of sheets of paper intended for use on their disc-like machine. The items of the program were printed in such fashion that, as the disc was rotated on the machine, each item would appear in sequence under windows on the cover of the device. In order to show illustrations, figures, or pertinent data relating to program items, a separate sheet of paper or ''panel'' was utilized.

Simple comparison of items from the Holland-Skinner program and our own indicated that we would have to pursue an independent study of presentation. Figure 2-1-1 illustrates the problem. Our items were of varying length, but many of them were longer than any items in the psychology program. Moreover, as we had gained experience in programing, we found it increasingly desirable to include within the frame any graphic representations that were necessary--rather than employ separate sheets or panels.

Experiments with Devices

For the sake of experiment, we placed our initial programs on 35mm slides which were then projected by the student using conventional Kodak Signet and Cavalcade projectors. The items were projected onto a small screen, and the automatic advance mechanisms of the projectors enabled the student to progress through the material with a minimum of effort. This easily solved the problem, of graphic illustrations, but it left much to be desired. One problem, for instance, was that two slides were required for each item in the program--one to present the stimulus; another the response. This struck us as being unnecessarily cumbersome and expensive.

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*Recently published as a programed textbook ''The Analysis of Human Behavior,'' by McGraw-Hill, New York.

A second method we tried used a Kodak Signet projector and a filmstrip of the program. This was less expensive than the separate slides, but still entailed two projections per item unless we wished to modify the projector.

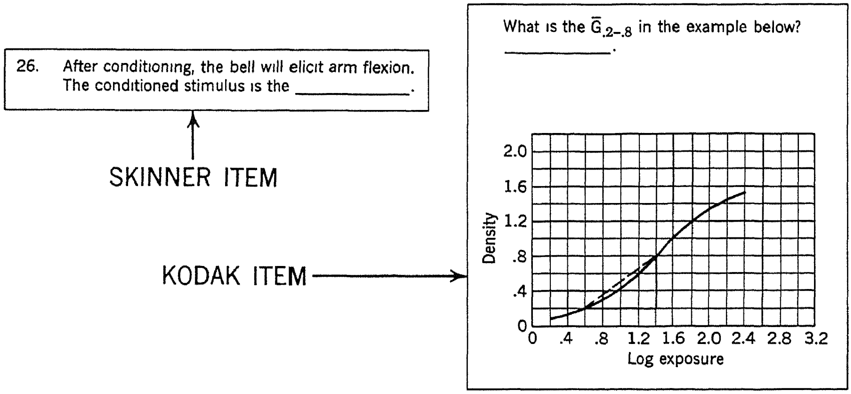
26. After conditioning, the bell will elicit arm flexion. The conditioned stimulus is the ____________.
SKINNER ITEM
KODAK ITEM
What is the $\bar{G}_{.2-.8}$ in the example below? ____________.
Density
2.0
1.6
1.2
.8
.4
0
0 .4 .8 1.2 1.6 2.0 2.4 2.8 3.2
Log exposure

Fig. 2-1-1 A comparison of items constructed for use in the Holland-Skinner psychology course and in our industrial sensitometry course. Note the difference in overall size, and also our emphasis on placing graphic material within the frame of the item to which it refers.

A third experimental set-up was devised which actually masked the lower portion of a 35mm slide, and, by means of a solenoid, the mask could be moved, and the response exposed for comparison. This solved the problem of two projections and suggested that, for certain applications, it might be possible and desirable to present learning sequences by means of standard audio-visual equipment with perhaps only minor modification.

Programed Books

As we made a series of studies on conventional film devices, we also considered the possibility of simply using programed textbooks or workbooks. At least in the early stages of program construction and revision this format seemed to be the simplest and least expensive means of presenting the program. The items could be typed or handwritten on cards or sheets; a sufficient number of copies could easily be obtained by the Verifax process; and we could quickly have the program ready for trial and evaluation. Our programers soon suggested a number of formats—including one gleefully dubbed "Kodatext"—in order to

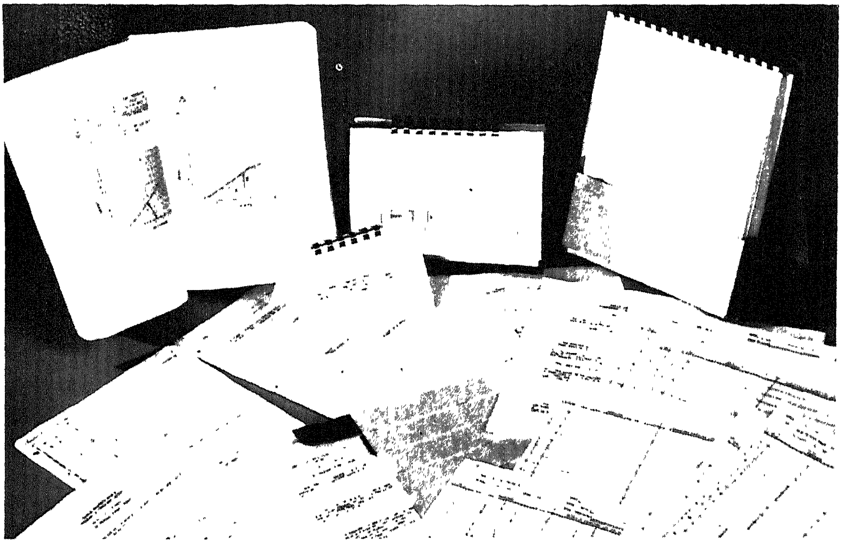

Fig. 2-1-2 Various programed textbooks, workbooks, and worksheets that have been utilized within the Industrial Training Departments of Eastman Kodak Company.

do necessary testing of the programs. Figure 2-1-2 illustrates some of these programed workbooks.

We liked the sheer simplicity of the programed "book," but there were some sobering second thoughts. The volume of paper consumed was considerable. Though we were just getting underway, it was already obvious that paper costs and handling would be significant. As the Klaus and Lumsdaine article elsewhere in this volume points out, their physics program for 500 students "required over 3 1/2 tons of paper and 120 dozen loose-leaf notebooks." It was one thing to deal with the workbook at the experimental level, it would be something else to adopt this as the medium for industrial training materials.

Programing Variations

On top of these considerations, it was evident that not all programs would follow the Skinner model. At least three variations were in use or under development. Norman Crowder had successfully programed materials using what he termed "intrinsic" programing. This differed from the Skinner material in that it characteristically employed multiple-choice responses, and required that the student have random access to the program, based on his choice of answers, rather than that the progress be in strict sequential order. Robert Glaser, among others, had spoken of the desirability of having a provision for "skipping" items in an otherwise sequential program, thus permitting the rapid learner to by-pass items which might seem redundant to him, but which were desirable for those students encountering difficulty with the program. John Barlow spoke of still a third form of programing which had come out of the work done by the Earlham College research project. Known as "conversational chaining," it was a variant of the Skinner model.

These diverse forms of programing made it difficult to adapt standard audio-visual equipment to the task of performing as a teaching machine. At this point, we felt that our whole effort to develop industrial programs was in jeopardy because of the "device" situation. Certain teaching machines began to appear on the market, and we studied each one in search of an answer to our needs. In some cases, they might represent a short-term solution, but with our concern over the eventual costs of paper and paper-handling, and our desire to limit our machine costs, we turned once more to the possibility of designing equipment to meet precisely the specifications recommended by our experience.

Machine Requirements

While we had not formalized any "design objectives," we knew that our minimum requirements for an individual teaching machine would include:

a. Versatility—The ability to present the various types of programing that might be necessary.

b. Standardization—While we wanted to present variant forms of programing, we wanted to do so by means of a standard reproduction format.

c. Economy—We were extremely conscious of the cost factor, and were determined to find a simple, inexpensive means of presentation.

At this point, we held a series of meetings with the engineering groups located in our Apparatus and Optical Division. We stressed to them our belief that the programs and the programers must dictate the necessary equipment, but that it was vital to the success of programed learning that we find devices which would offer versatility, standardization and economy.

Some form of film device seemed the answer to our needs. In this belief, we were certainly not unique. Klaus and Lumsdaine had concluded in their study, "it is likely that the presentation of auto-instructional material on film may be the most economical procedure." Many other individuals had expressed the belief that, over the long run, a film device could best satisfy the needs of the field.

After the initial explanatory meetings with the engineers, and after considering various applications of filmstrips and 16mm motion picture cassettes, we narrowed our study to an exploration of microfilm handling equipment. Its known capability for miniaturization, and its economy in reproduction meant that we would be starting in a promising direction.

Planning and development now began in earnest with the design engineering staff of Recordak, the subsidiary of Eastman Kodak which specializes in microfilming. Having again explained the needs of the program, and how we wished to utilize this equipment in industrial training, we reviewed the devices that might be adapted. There were several standard devices that could handle microfilm programs, and could allow the sequential and random access that was required. Unfortunately, these devices were designed to handle rolls and magazines of microfilm—and by a little calculation it appeared that a single roll of 16mm microfilm could contain the entire Holland-Skinner program, and at least another of similar length. Our reaction was that this would mean having the entire course "in use" whenever a single student was working on a single lesson.

At this point a parallel development came to our rescue. Quite independently of our own research, a Recordak engineer had been developing a new concept of microfilm unitization, looking to greater flexibility in the handling of "book" records-on-microfilm than is afforded by the conventional 100 ft roll form. His slide-track card innovation permits single or multiple strips of micro-film to be sandwiched in card mounts. Although the film strips are not visible, the individual images can be projected one by one on the screen by manual movement of the film strip within its own slide-track (see Fig. 2-1-3).

Programed material could be microfilmed, cut into strips on the basis of lessons or units, inserted in the card, and used on the teaching machine as required. Additional lessons or units could be stored or filed until needed by the student. No single student need ever "monopolize" more than four or five units at a time, and, of course, far fewer "sets" of any given program would be required to handle large groups of students. The card concept offered an additional advantage. It was the means for filing, storage, and handling—built right into the teaching machine system.

In order to utilize the card system, a new microfilm reading device had to be designed and constructed, but this presented a relatively minor problem once the means of handling the programed materials was determined. The reader would have an indexing device which would permit either sequential operation, with the facility for skipping certain items, or a non-sequential,

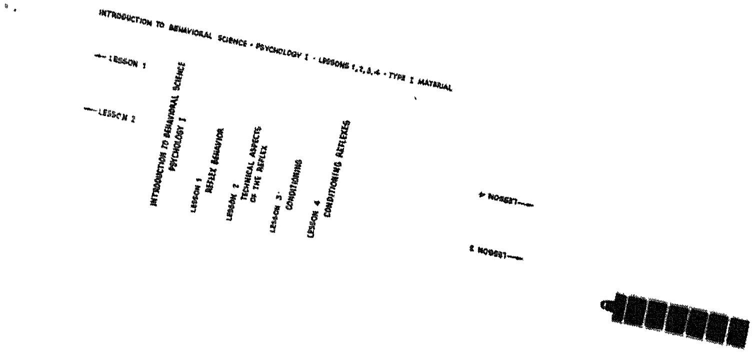
INTRODUCTION TO BEHAVIORAL SCIENCE · PSYCHOLOGY I · LESSONS 1,2,3,4 · TYPE I MATERIAL
LESSON 1
LESSON 2
INTRODUCTION TO BEHAVIORAL SCIENCE PSYCHOLOGY I
LESSON 1 REFLEX BEHAVIOR
LESSON 2 TECHNICAL ASPECTS OF THE REFLEX
LESSON 3 CONDITIONING
LESSON 4 CONDITIONING REFLEXES
NO0687
NO0681

Fig. 2-1-3 Slide-track card used for storing, filing, handling, and projection of programed materials in the Recordak Mentor Teaching Machine. One unit of film is partially withdrawn to demonstrate how it is utilized within the device.

random-access operation. The viewing screen would be large enough to permit the incorporation of illustrations, graphs, charts, and other materials into the program.

Machine Prototypes

In June 1960 we had our first prototype (Fig. 2-1-4). Known as the Mentor, it employed strips of 16mm film. It permitted the handling of both sequential and intrinsic programs, and it had an auxiliary answer device which could be employed for use with constructed response items (Fig. 2-1-5). Throughout the summer of 1960, we tested and studied the equipment, and experimented with the filming of programs. In the fall of 1960, we put the device on display at the seminar sponsored by the Foundation for Research on Human Behavior. Since that time, we have started building additional models of this first prototype, with only slight modifications as indicated by our experience, for use in Eastman Kodak.

While the first model of the equipment had been designed to meet the needs of variant forms of programing—a point we feel will be more important as time passes—we recognized that for the present and immediate future, most programs under construction are patterned after the Skinner model. For this reason, we constructed a second model of the device which was considerably smaller and less expensive to build (Fig. 2-1-6). This second prototype, or Mentor Model 2, can present standard sequential programs, and can "skip" appropriate items as required:

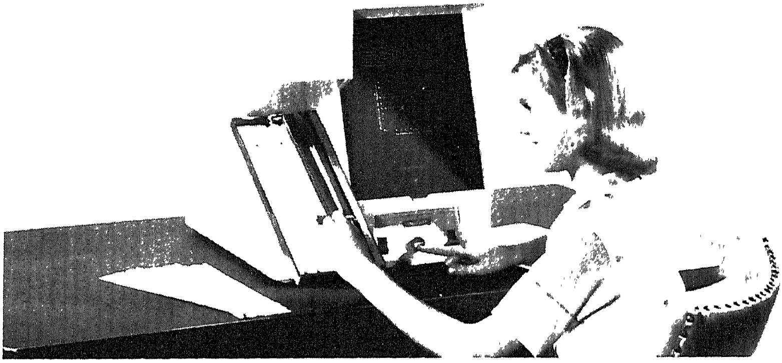

Fig. 2-1-4 The Recordak Mentor Model 1 Teaching Machine in use in industrial training. In this illustration, the device is being used in the unlocked mode for non-sequential subject matter, and the optional answer device is not in use since a constructed answer is not required.

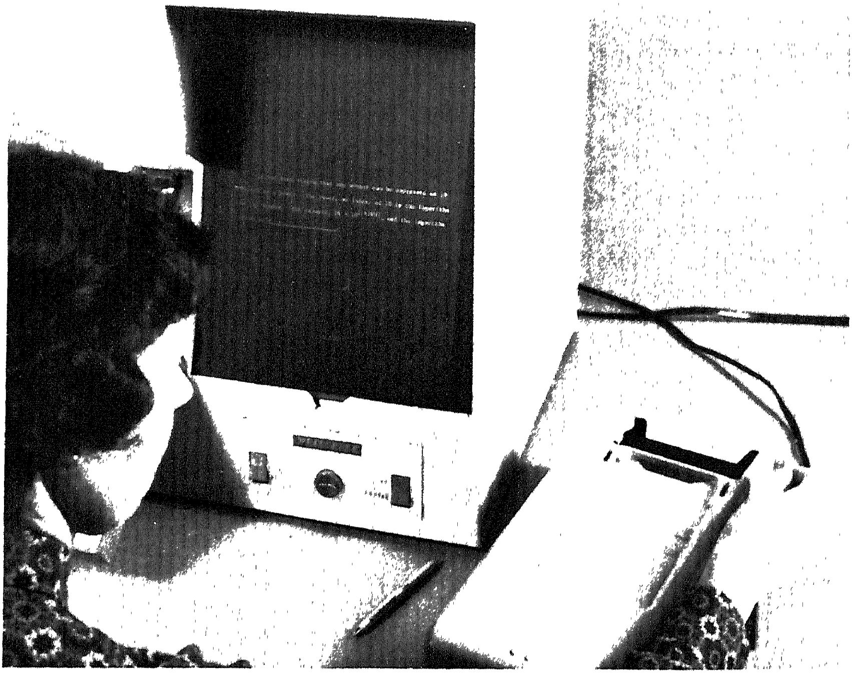

Fig. 2-1-5 The Recordak Mentor Model 1 Teaching Machine shown in use on an industrial subject. Because this is a sequential, constructed answer-type program, the answer device is employed in this mode of operation.

It utilizes the same basic film and envelope system so that compatibility can be achieved.

Equipment Design Factors

The factors which we feel are most important in the design of the equipment, the factors which are vital to our concept of teaching machine utilization, are these:

a. Machine capability for handling various program formats and programing techniques even within the same lesson or unit.

b. Provision for integrated use of graphic illustrations directly within the program frame.

c. Simplicity of producting microfilm programs from typed or printed original materials.

d. Compactness and convenience of program storage through miniaturization.

e. Durability of programs including re-usability and freedom from student or machine damage.

f. Capability of using color materials, at low cost, when desirable or required by the program content.

g. Ability to include "cheat-proof" guards against student violation of the program design—use of the guards being at the option of the programer.

h. Capability of producing either short-run or long-run quantities of programs at reduced material cost.

i. Utilization of programed materials by lesson or course unit to permit reduced program overhead.

j. Machine operation of an extremely simple and relatively service-free device meaning uncomplicated student use and little repair.

Our plans for future development of such devices include the addition of audio facilities to the "system" so that the student may hear and record appropriate stimuli and responses. Moreover, the systems approach to the teaching machine lends itself to the possible addition of various recording devices which may be desirable from the standpoint of program research and evaluation—apart from the normal use of the machine in the learning situation.

All of the research and development done on our equipment was directed toward its use by the Eastman Kodak Company for industrial training within our own plants. Following the construction of the first prototype, consideration naturally broadened to include possible commercial applications of the device. In the fall of 1960, the Educational Microfilm Systems Department was established in the Recordak Corporation. We were convinced by this time that microfilm is the most versatile and satisfactory

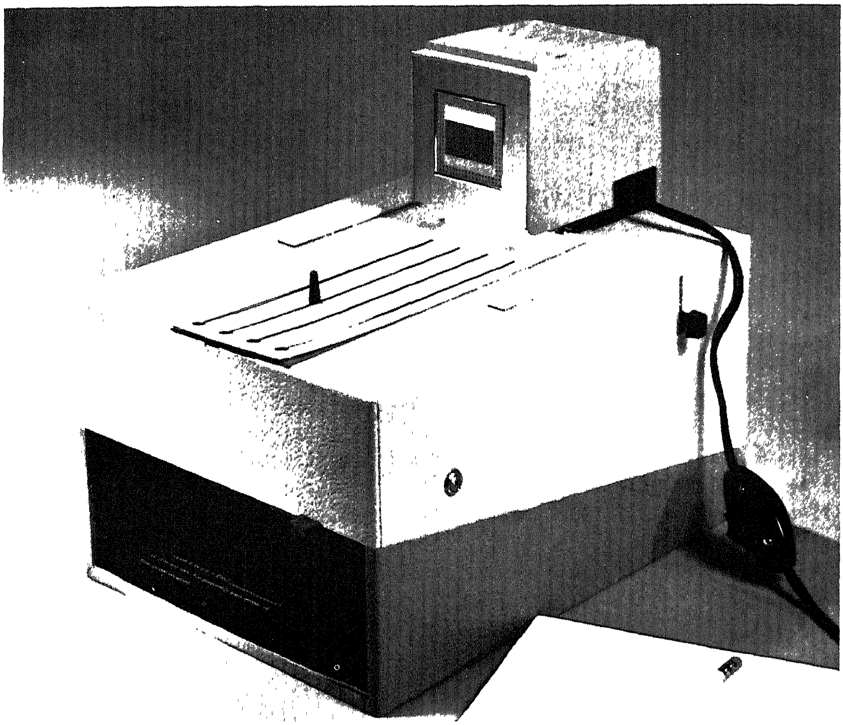

Fig. 2-1-6 The Recordak Mentor Model 2 Teaching Machine that is used for sequential, constructed answer type programs with the facility for "skipping" items as directed by the program.

medium for preparing and utilizing efficient systems for programed learning.

The new department was formed to offer technical assistance in systems and microfilm techniques to individuals and organizations engaged in the assembly and use of educational material in programed format and to continue the study of design features for microfilm equipment that will be required. Eastman Kodak Company has continued the research and development of learning programs and learning sequences using standard audio-visual equipment, so that, depending on the nature of the students, the material and the learning task, an effective means of program presentation may be selected.

In the process of investigating this field, we have raised some questions, the answers to which have had a strong influence on our thinking. Because others have been asking similar questions, our tentative conclusions may be of interest. In time, we expect to have firm answers.

WHY WORRY ABOUT LEARNING PROGRAMS AT ALL?

Industrial training will always require new approaches and new conditions. Two trends in training needs, however, seem to call specifically for the examination of programed learning. The first trend is that toward higher and more complex human skills. The mechanical engineer must keep abreast of changing developments in electronics and hydraulics because our new integrated systems require inter-disciplinary handling. The second trend is related to the first. We must further individualize our training efforts because the job needs of our people will become more unique, and we will find a rising proportion of training assignments involving a single individual, or at most a very limited number.

Programed learning seems promising in light of both these trends. Programs can teach higher skills, and areas like modern mathematics, electronics, thermodynamics, and the physical sciences are already being programed. Just as importantly, the learning program is designed to be auto-instructional. The student will learn individually by mastering the program.

BUT IS PROGRAMED LEARNING EFFECTIVE IN PRACTICE?

In a photography course, the students had to work with logarithms in order to master sensitometry. In any class one could expect a number of individuals who needed to learn about logarithms, or at least have a brief refresher course. This meant other individuals had to mark time; it also meant the time of an instructor. One programer produced a sequence of 103 frames on logarithms. By mastering this unit, the student learned all he needed to know to solve problems in sensitometry. Since that time, it has not been necessary to conduct classes in logarithms, or hold up class progress, or employ an instructor to teach in this connection. The students schedule themselves, perform the programed sequence on a teaching machine, and master logarithms quickly.

In another case, the clerical staff of a department needed skill in statistics. A pre-test showed most scores ranked in the forties and fifties. The girls took the first three units of a programed course in descriptive statistics. They scheduled themselves over a six-week period to meet the convenience of their office workload. At the completion of the material, the lowest score on the post-test was in the nineties. Supervisory personnel were so impressed that they began the programed course.

One more example: another programer was teaching a unit on human motivation by means of lecture-discussion. He programed the same information; then conducted an experiment. Two groups of supervisors were given the learning program only; three groups of supervisors attended the lecture-discussions. Later tests showed that the "program" students retained twice as much of the motivational spectrum developed by the instructor. Thirteen specific questions showed the "program" students excelling on nine, most by significant differences. One question showed no difference. Three showed the "conventional" students had a higher percentage of correct answers. The instructor concluded that the students who had worked individually with the material had gained equal—if not higher—mastery without benefit of class or instructor. This being his first attempt at programming, it is safe to assume there will be even greater improvement in the future.

WHERE DO YOU OBTAIN THE PROGRAMS?

For the time being, this is a problem. Programed materials are just now becoming commercially available, and it will certainly be some time before the training specialist will have a choice of programs in a wide variety of subjects. A rapid growth in the number of available programs is anticipated, however, because the publishers are obviously accelerating their efforts to reach the market. The problem may well be to limit publication to effective programs.

Nevertheless, we expect to continue programing sequences in areas unique to our own training needs. Currently we are working on some 24 projects related to our instructional courses. Few, if any, of these would have general applications outside the Eastman Kodak Company, and most companies will face the same situation. General fields, such as statistics, will be covered by commercial programs. Unique company needs must be self-programed, or developed by consultants under contract.

HOW DO YOU DETERMINE THE SUBJECTS TO BE PROGRAMED?

If a suitable program is available for purchase, we use it. If it is material which we must program for ourselves, we select it on the basis of criteria which include:

a. Known difficulty with the present training approach (as in the case of the unit on logarithms discussed above).

b. Number of students to be trained.

c. Permanency of the subject-matter.

d. Estimated time for development.

If we know a present training method leaves much to be desired, and if we have a fairly large number of students who will need this material over a period of time then it would seem to be a suitable area to program. The subject matter should be relatively stable, otherwise the program will quickly become obsolescent. Development time is an obvious consideration in assigning priorities.

We have learned one valuable lesson in selecting a subject for programing. Rather than program a "course," we break out units or lessons and program these. This means that the material can be fitted into the next presentation of the course. Thus, we have prompt field-testing and feedback of results. Programers like this approach because it gives them known dates for using and evaluating the sequence before proceeding on to additional units.

The units can then be fashioned together into a sub-course or course. After programing the unit on logarithms, a unit on sensitomety was developed; now other areas of photography are being programed. Eventually they will probably be combined into a total course in basic photography. We will be gaining benefit from each unit of the course, however, as soon as it is completed.

ARE SOME SUBJECTS MORE DIFFICULT TO PROGRAM?

Generally, the more logical the subject-matter, the more easily it can be programed. This is why there are several programs in algebra, and very few in the social sciences.

There is no reason, however, to believe that more difficult, conceptual learning cannot be programed. Work is being done on several languages, the Old Testament, philosophy, and various sciences. Our own 24 areas of programing include units from every portion of our industrial training curriculum. We wanted to find out if there was some subject which could not be programed. We have found none to date.

Programing in some areas has proceeded at a much faster rate than in others. Our tentative conclusion is that the difference is as much a function of the programer as it is of the material.

HOW DO YOU OBTAIN PROGRAMERS?

Initially, two of us learned to program by trial and error. Later, we wanted to train a number of programers so we developed a two-week workshop covering principles and techniques of programing. The students sampled programs developed by others, and then constructed short practice units of their own. This approach was refined by experience, and some twenty people have now been trained within the company.

Not all the students developed into programers. A number of them did not enjoy the work. On the other hand, at least two individuals became interested in programing as a result of reading articles in the local press. They talked with us, took away literature and programs, and tried their hand at the game. Both became excellent programers.

Recently, our prople participated in a course in programing held at the University of Rochester. The students were teachers, administrators, and industrial training people. That course, plus our experience, and three summer workshops planned for this year will give us an increased opportunity to determine the qualifications of people who make good programers. Now it is known that a programer must be intelligent, resourceful, somewhat creative, and knowledgeable in the subject matter. Given these qualifications, he can be taught the techniques and the methodology.

WHAT ARE THE COSTS AND TIME INVOLVED IN PROGRAMED LEARNING?

The commercial programs that we have used have ranged in price from $4 to $20. We feel that this cost, and the investment of time by the person taking the course, have been most reasonable when measured against learning effectiveness.

The cost of developing our own programs must, of course, be taken into account. At present, our programers spend 20-30 minutes per item. This includes initial writing, sequencing, and first revision following field testing. Additional time must be spent on later revisions. This rate of programing permits substantial savings in later instructional time, and student learning time.

Most of our programing has been done in areas that are now being taught by conventional methods. If we were to program entirely new material, it would, of course, take more time than if we were to develop lesson plans and lecture notes. Programed sequences are much more demanding and require more rigorous analysis of the subject matter.

HOW DO YOU ADMINISTER PROGRAMED LEARNING?

We provide private rooms equipped with teaching machines and programed textbooks. The student may reserve the room at any time during the day that fits his own schedule. He then proceeds through the program at his own rate.

Machines and programs have also been made available to individuals to take to their desks. The special room, however, tends to reduce interruptions, and is a superior learning environment. In almost all cases, this training takes place within the regular working hours of the individual.

WHAT DO THE PEOPLE THINK ABOUT PROGRAMED LEARNING?

Student reaction has generally been quite favorable. Many found it exciting, "I thought it was wonderful!", "It was very intriguing!". More of them found it demanding, challenging. "It forces intense concentration." "I had to give it my complete attention." Almost all had the feeling they were learning. "I learned a lot." "I wanted to go on."

To learn more about how people felt, and particularly what applications they had made of programed learning, we conducted a survey of the supervisors who participated in the experiment on teaching human motivation. The results are shown in Table 2-1-1.

Table 2-1-1. Results of Survey of Supervisors

	Percent answering "Yes"	
Question	Lecture-discussion	Programed learning
Have you given any thought to this material?	73	100
Have you discussed it with anyone?	60	78
Have you tried to explain it to anyone?	34	57
Have you made any effort to apply some of its ideas?	41	100

This leads to the tentative, but very interesting, conclusion that programed learning students come away from their experience with a higher disposition toward action and application. This is all the more important if you define industrial training in terms of "changing behavior."

Those supervisors whose people have had training by means of learning programs have, in almost all cases, been impressed with its efficiency and effectiveness, and there have been instances where they have taken the material themselves as a result of student comment.

Then there are the training men. Not all of them have been enthusiasts. As evidence mounts that people do learn by this approach, more instructors have been attempting to write programs, and asking to be kept up-to-date on available commercial programs related to their field of activity.

There have also been negative reactions—primarily from the students. Some simply "do not like" programed learning. They say they are accustomed to classes, teachers, and regular textbooks, and do not wish to use such a different approach to learning. Several who felt this way acknowledged, however, that they had indeed learned material by means of the program. A very few of the students seem particularly ill-at-ease with the machine. They felt better about using the programed textbooks. A more serious problem, though, is the contradictory feeling of students that the same material is developed too rapidly or too slowly for most effective learning. This difficulty must be studied much more thoroughly, and can probably only be solved by constructing parallel, but differently paced, sequences.

IS THE TEACHING MACHINE IMPORTANT?

We definitely think so. We know students can learn by simply using the learning program. We believe, however, that the machine enhances learning, and contributes positively to the learning process.

The programer designes his material so that students will encounter each new bit of information in proper order. This can be better guaranteed by means of a mechanical device than by handing the student a programed textbook which he may or may not use as intended. The device allows recording of student's progress through the material, and provides data to analyze, in order to improve subsequent student use of the material.

Those of you who have encountered some of the variant forms of programed textbooks, with scrambled pages, reversed reading, and up-side down printing will sympathize with our desire to eliminate impediments between the student and his mastery of the program. We believe the teaching machine gives the student a convenient, simple, and straight-forward means of reaching his goal, and that this is most desirable.

Cost may seem an odd reason to cite for using teaching machines. It appeared, at first, that a simple system using paper sheets would be the cheapest method we could find. The sheer volume of paper consumed, and its preparation, filing, storage, and handling far exceeded the initial cost estimates. We began a research study on teaching machines largely because we wanted economy and miniaturization. We found, however, that microfilm permitted us to do the job of training, and effect savings in the process. We are now employing the Recordak mentor teaching machines in our industrial training programs.

A final thought on the use of teaching machines is that they permit handling all known variations in programing because their presentation to the student can be standardized through the common ''format'' of the microfilm. This eliminates the need for struggling with various shapes and kinds of media and materials.

Our students like the ease and clarity of machine presentation. They tend to find the material more "absorbing" and "demanding" when used in the machine. There are a few who simply do not like using teaching machines, but most negative comments concerned mechanical and design deficiencies in the earliest experimental models.

THE FUTURE OUTLOOK FOR PROGRAMED LEARNING IN INDUSTRIAL TRAINING

You can see that we are optimistic. It will be 3-5 yr before a wide variety of programed materials is generally available. If interest continues at the present rate, however, that time may be greatly reduced.

Without doubt, publishers will make more rapid strides in offering programs to the market; universities and research centers will produce more definitive information on learning behavior, programs, and programers; and more companies will undertake the development of programed materials to fit unique training needs.

Our experience of the last three years is proof to us that time spent in exploring industrial applications of programed learning is well spent. We have found such learning to be effective, efficient, and economical. It has given us new insight into adult learning, and has provided us with new opportunities to improve the learning experience.

The Effectiveness of Programed Instruction: Experimental Findings

By J. L. HUGHES
International Business Machines Corporation

A series of three experiments was conducted in October, November, and December of 1960 that compared the effectiveness of programed instruction with conventional classroom instruction. The first 15 hr of the IBM 7070 training course for customer engineers given at Poughkeepsie were selected for this comparison. The programed-instruction material (see Appendix A) was presented by means of programed textbooks. Six experimental classes totalling 70 men and two control classes containing 42 men were used. The results were as follows:

a. Programed instruction reduced the time needed for presenting the subject matter from 15 hr to 11 hr, a saving in time of 27%.

b. On a comprehensive test of the material covered, the programed-instruction group averaged 95.1, compared with 86.2 for the control group. The difference of 8.9 points represented a learning gain of 10%. The programed-instruction group also showed a smaller dispersion of scores, with 89% scoring 90 or above compared with only 43% for the control group.

c. Replies to a questionnaire administered to the programed-instruction group were highly favorable. Of the group, 87% liked programed instruction better than conventional classroom instruction, and 83% favored using programed-instruction in future courses in place of conventional instruction.

Thus programed instruction is immediately applicable to reducing the number of days a student spends at a central training center and, eventually, to decentralizing the teaching of many courses to branch offices with resulting substantial economies. In addition, the improvement in learning possible with this technique should produce better trained sales, systems, and service staffs. Customers could also be trained more efficiently. Programed instruction could be expected, therefore, to aid sales and customer-relation activities. Management, technical, manufacturing, and clerical training also could be expected to benefit from the use of programed instruction.

A DESCRIPTION OF THE EXPERIMENTS

In March, 1960, a team composed of a customer-engineering instructor and a psychologist was formed to prepare programed textbooks for the Introduction and Programing Section of the 16-week course on the IBM 7070 given to customer engineers at Poughkeepsie. The services of a psychological consultant from the American Institute for Research were also secured for one day a month to review the materials prepared by this team.

By the end of September, 719 frames of programed-instruction material covering the first 15 hr of the IBM 7070 course were completed. The topics covered were the names and functions of units of the 7070; data flow; bit coding; instruction, data, and index words; and the computer-program step. To test the effectiveness of these materials, the following experiments were carried out:

a. Two classes of 21 students each that began during September were designated the control classes. They were taught the material by two different instructors in 15 hr using the conventional IBM classroom method (lecture-discussion). To measure what they had learned, these classes were administered a comprehensive 2-hr examination covering the entire instructional period. A sample of the questions contained in this examination is given in Appendix B.

b. Six classes consisting of 70 students made up the total experimental group. Two of these classes reported for training each month from October through December, 1960. They were instructed by means of programed instruction materials only. The instructors remained in the classrooms but confined their activities to passing out the programed instruction materials and briefly answering the few questions put to them by the students. These classes also took the comprehensive subject-matter examination. In addition, they completed a questionnaire asking them to evaluate programed instruction (Appendix C).

To test the comparability of the control and experimental groups on various background data, information, such as age, educational level, length of customer-engineering experience, and length of previous computer experience, was collected by means of another questionnaire (Appendix D). A test of mental ability (Programer Aptitude Test) also was administered.

THE RESULTS

The subject matter covered in these experiments took 15 hr when presented by the standard classroom method. The same information was covered in 11 hr by programed textbooks, a saving of 27% in presentation time.

On the comprehensive 2-hr test covering the material presented in the entire instruction period, the control group had a mean of 86.2 compared with 95.1 for the experimental group.

The experimental group thus scored an average of 8.9 points higher, a learning gain of 10%. This difference was found to be statistically significant at the 0.01 level.

Not shown in Appendix B are the mean test scores for each of the three successive experimental groups, consisting of two classes each, that started training in October, Novermber, and December, 1960. These means were 95.7, 95.0, and 94.7, respectively, which show the consistency of learning achievement when programed instruction is used over a period of time with different classes.

The distribution of test scores for the experimental and control groups is given in Table 2-2-1. Note the greatly reduced dispersion of achievement for the experimental group. Almost all (89%) of the experimental group scored 90 or above on the examination, with the rest scoring in the 80's. For the control group, however, only 43% scored 90 or over, and the rest ranged down into the 70's. (The standard deviation of the experimental group was 4.0 compared with 7.4 for the control group.) One of the effects of programed instruction thus appeared to be that more trainees attained a high level of achievement in the course.

Table 2-2-1. Means, Standard Deviations, and Distributions of Achievement-Test Scores for Control and Experimental Groups

Achievement test score	Control group ($n = 42$)		Experimental group ($n = 70$)	
	N	%	*N*	%
95-100	5	12	49	70
90-95	13	31	13	19
85-89	7	17	5	7
80-84	9	21	3	4
75-79	6	14		
74 and below	2	5		
Totals	42	100	70	100
Mean	86.2		95.1	
Standard deviation	7.4		4.0	

There were no significant differences between the experimental and control groups in age, educational level, months of customer-engineering experience, or previous computer experience that affected the achievement test scores. The experimental group, however, was significantly higher (58.2 vs. 51.2) on the Programer Aptitude Test (PAT), a measure of mental ability (see

Table 2-2-2. Means and Standard Deviations on Background and Aptitude-Test Variables for Control and Experimental Groups and Their Correlation with Achievement-Test Scores

Variable	Control group ($n=42$)	Experimental group ($n=70$)	Product-moment correlation with achievement-test score
Age (years)			
Mean	28.8	29.3	-0.01
S.D.	5.7	5.4	
Attending college (%)	17	34[1]	0.22[2]
CE experience (months)			
Mean	62.3	63.1	0.01
S.D.	57.2	38.8[3]	
Previous computer experience (%)	38	43	0.31[2]
Programmer Aptitude Test			
Mean	51.2	58.2[4]	0.44[2]
S.D.	12.1	8.5[4]	

[1] The difference in educational level (percent attending college) between the two groups appeared to be large, but it was not statistically significant. Educational level, however, correlated significantly (0.22) with achievement-test scores. Since educational level also correlated significantly (0.31) with PAT scores (which were used to adjust achievement-test scores), no additional adjustment of achievement-test scores based on educational level was considered necessary.

[2] Correlation coefficients of 0.25 and 0.22 or higher were found to be significant at the 0.01 and 0.02 levels, respectively.

[3] The difference in standard deviations for the experimental and control groups on length of customer-engineering experience was significant at 0.02. In view of the low correlation (-0.01) of customer-engineering experience with achievement test scores, however, no adjustment in achievement test scores was made for this variable.

[4] Differences in PAT means and standard deviations for experimental and control groups were significant at 0.02; none of the other differences between means and proportions was significant.

Table 2-2-2). It was also found that PAT was significantly correlated (0.44) with the trainees' achievement-test scores. A statistical technique (analysis of covariance) was used, therefore, to adjust the achievement test scores to eliminate the effect of differences in PAT scores between the two groups.

When the achievement test scores were so adjusted, the experimental and control group means became 94.7 and 86.7 respectively. The difference between the means of 8.0 points was only slightly less than the difference of 8.9 for the unadjusted means and remained significant at the 0.01 level. It was concluded, therefore, that the difference in achievement between the experimental and control groups could not be attributed to the effect of differences in aptitude test scores.

On the student Questionnaire administered anonymously to the six experimental classes, the replies of the trainees were very favorable to programed instruction (Appendix C). Of the total group of 70 men, 87% liked programed instruction more than conventional instruction, and 83% said they would prefer using it in future IBM courses. Only 6% liked programed instruction less than conventional instruction, and only, 13% would have some objections to using it again.

Most of the dislike and objections occurred in one class where the instructor, in recording the time for completing different units of the materials for the purpose of the experiment, caused the students to feel that they, and not the materials, were being timed. In other classes, where the timing was done less obviously, the dislike and objection to programed instruction was much less.

It was interesting to note that practically all of the students realized the advantages of programed instruction over conventional instruction. All of the group stated before taking the examination that programed instruction was more effective than conventional instruction, and 93% also found it less difficult. In addition, 60% reported that programed instruction required less home study. This suggested that the learning gain might have been achieved with greater savings in total class and home study time for most of the students than indicated in this experiment, which measured only class time. It also should be noted that it was the opinion of observers that the class time could be further reduced without significantly affecting learning achievements.

The Student Questionnaire also provided the trainees with space to indicate what they particularly liked (Item 6) or disliked (Item 7) about programed instruction. They were also given the opportunity to write in any additional comments (Item 8) that they wished to make. Appendix C summarizes the most frequent comments made regarding each of these items.

The responses to Item 6 (liked) gave the main reasons for the trainees' favorable reaction to programed instruction. These included relative speed and ease of learning, individual nature of instruction given, and logical presentation of material. The comments on Item 7 (disliked) related mostly to complaints about the timing, mechanics, repetition, difficulty of review, and boredom from too much PI without classroom discussion. This type of comment should be greatly reduced in the future with improvements in materials and better integration of these materials with class discussion groups. The responses to Item 8 were similar to those included under Item 6 and 7, and also contained a number of recommendations for improving the materials and using them in future IBM courses.

A DISCUSSION OF RESULTS

The promising results obtained from this series of experiments indicate the potential advantage in time, cost, and achievement by applying programed instruction to other areas of training. These results corroborated the positive findings found by other investigators in training experiments outside of IBM.

These findings also suggested several applications to training programs that promise important economies. The immediate one is the reduction in the number of days that students need to spend at training centers in a given course. This reduction can be translated immediately into savings in the direct, daily-living expenses of these students and, eventually, into reductions of other educational costs.

The second ultimate application is the decentralization of training by enabling people to be trained in basic courses at the branch offices or customer's offices. Because trainees work individually on programed instruction materials, a training package can be prepared for distribution to the field that will teach the required subject matter. The possible economies in this method of instruction are easily visualized.

Another result of programed instruction would appear to be better trained sales, systems and service groups, with attendant advantages to sales and customer relations that cannot be estimated directly. Similarly, customer training also could be expected to improve, thereby enabling customers to use the equipment more efficiently and, again, facilitating good customer relations. In management, technical, manufacturing, and clerical training areas, programed instruction could be applied to similar advantage.

In spite of the additional commitments in funds and manpower that setting up program-writing teams would require at the present time, any company can ill afford to postpone the long-term gains and economies in training programs that programed instruction promises. But there is the need for more research on the programed instruction technique. Because programed instruction is still in its infancy, a number of improvements in technique leading to greater efficiency still can be expected.

Books as Teaching Machines: Some Data

By HOWARD O. HOLT and JOSEPH HAMMOCK
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Since the early days of the current wave of enthusiasm for teaching machines or self-instruction methods, there has been a prevailing question as to whether programed materials presented in book form could teach as well as comparable materials presented by machines. Informal reports have indicated that many persons who have worked with both media have given up machines and have turned to using books entirely. At the time this study was initiated, no published evidence bearing on the relative efficacy of books and machines was available. Since then, however, there have been two studies published as institutional reports—one by Eigen and Komoski (1960) and the other by Roe, et al. (1960)—both of which have supported the position that books are as effective as simple machines.

Because we felt that an adequately controlled comparison of books and machines would be of value, the present study was introduced into an already planned, larger study of programing and auto-instructional methods vs. traditional methods. The gist of the finding is that, under the conditions of the study, the notion that programed books teach equally as well as programed teaching machines cannot be rejected. The remainder of this article describes the conditions under which this result was obtained and presents our view of its implications for the choice between books and machines.

The present study seems to have the following unique aspects when compared with the studies cited:

a. It is based on a much longer course; it took subjects an average of 51 hr to complete the course.

b. Learning in the course is concentrated so that any differential fatigue, boredom, or motivational effects can accumulate. (Specifically, the subjects worked 6, 7, or 8 hr a day, depending on school policy, for five days a week.)

c. Subjects (technicians) are drawn from a lower aptitude level than the college and high-school students in the other studies.

d. The study provided for replications across three cities in widely different locations.

The course content is basic electricity, which normally is taught as the fundamental course in a series concerned with electronics maintenance in the telephone business. The materials were programed for auto-instruction by a team consisting of Dr. Myron Woolman, a psychologist, and Mr. Glenn Valentine, an electronics supervising instructor from a telephone company. The program, in general, is of the Skinnerian type that requires constructed responses, but it deviates in the following ways:

a. Some of the items are purely informational and do not require a response.

b. Periodic diagnostic tests are given, after which the learner either goes ahead or repeats portions of the program.

c. The learner has an answer list of some 30 items in front of him at all times.

The student makes a total of about 3,500 constructed responses as he works through the program.

The teaching machine used was one designed and constructed by the Bell Telephone Laboratories because, primarily, at the time the study started, a suitable machine could not be found on the market. Figure 2-3-1 shows the machine at a student work position. The machine has the usual provisions for the frame or item to appear in a window. The student writes his answer in context, and then turns a knob that results in his answer moving up under glass and in the confirming answer being exposed. In operation, this machine is much like the Rheem-Califone Didak and the Foringer Machine. Figure 2-3-2 shows the machine open for loading. The program is printed on 5-in.-wide paper tape in rolls of up to 225 ft in length.

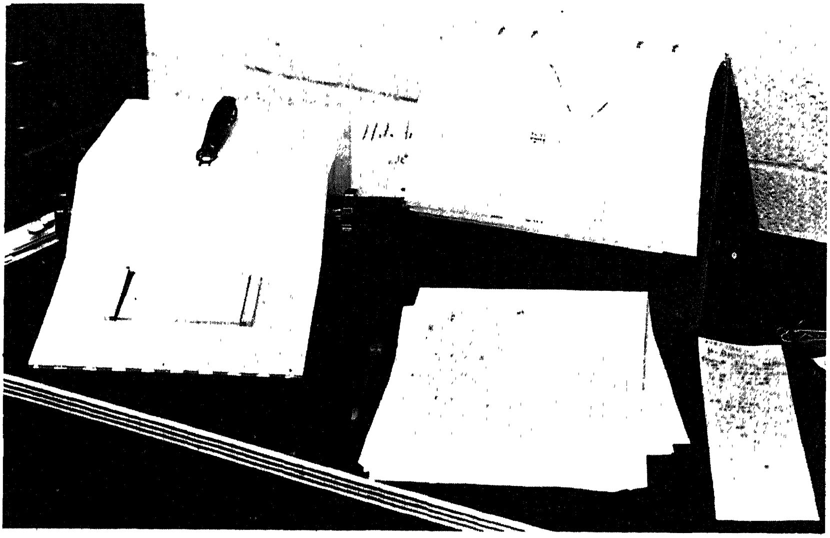

Fig. 2-3-1

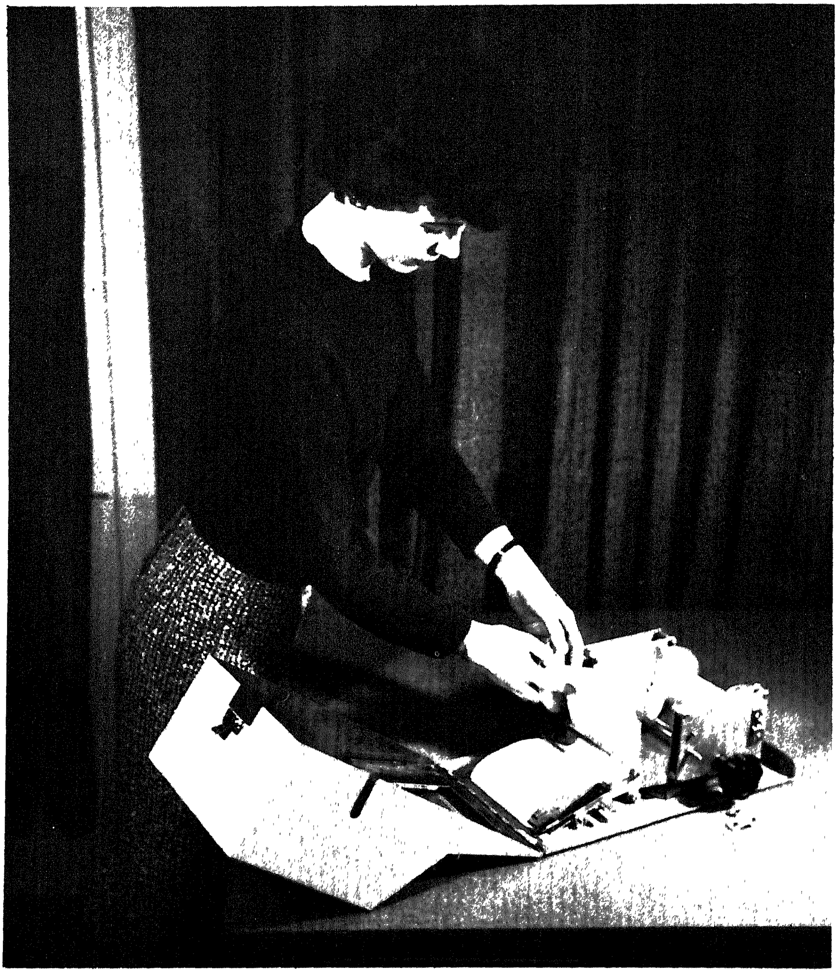

Fig. 2-3-2

Figure 2-3-3 shows the books or booklets that were used in the study. The program in the book is identical to that presented by the machine. The book materials are fastened into two rings of a four-ring notebook. The student reads an item and writes his response in context. He then turns the page and sees the confirming response on the next page. The next frame is on the following page and so on. The subjects were instructed not to look ahead or to turn back but to use the book as if it were a machine. However, the policing of this procedure was not at all rigorous, and "cheating" was observed to occur.

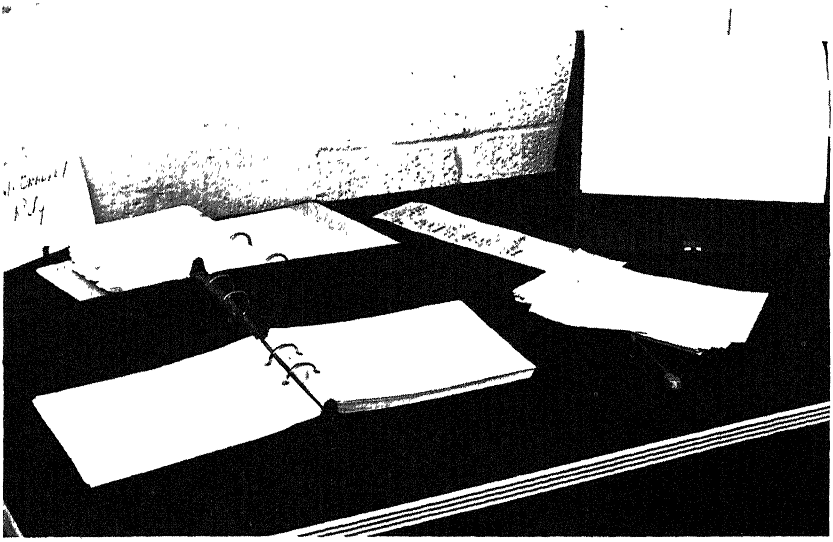

Fig. 2-3-3

Two predictor or control variables were measured prior to the commencement of training for use in covariance adjustments. These were the following:

a. An IQ estimate based on the Otis Employment Test (Test 2, Form B).

b. The degree of the student's prior knowledge of electricity (pre-course performance on items from course tests).

The program was administered to two successive classes in each of three Bell Telephone companies. Each class consisted of subjects who were assigned at random to the book and machine treatment conditions. Table 2-3-1 shows the experimental design and number of subjects completing the course. Originally, there were

Table 2-3-1. Experimental Design and Size of Sample

Cities and replications		Book	Machine
L	I	4	5
	II	4	5
M	I	4	5
	II	3	5
N	I	6	6
	II	7	9
Total's		28	35

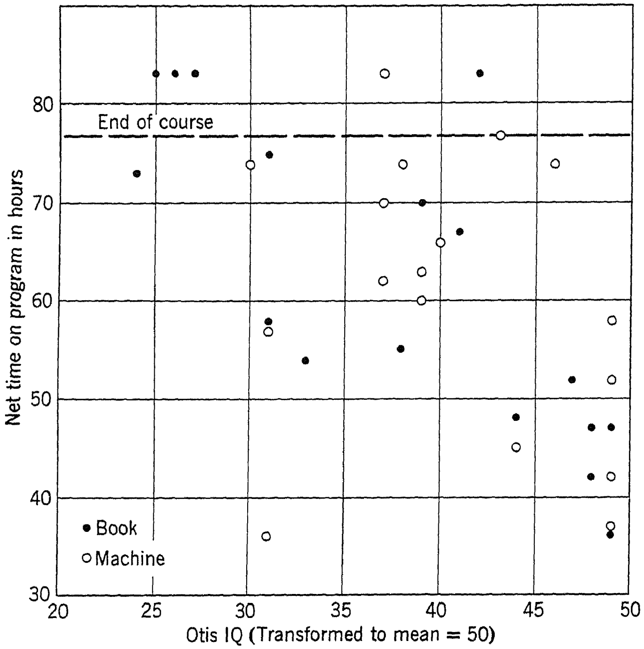

Fig. 2-3-4 Time on program as function of Otis IQ for subjects with IQ's less than mean.

34 and 36 subjects assigned to books and machines respectively. Of these, 28 and 35 completed the course. This shows a loss of six subjects on books and one on machines. Of the six losses on books, two were due to illness and three were probably due to low IQ's. Figure 2-3-4 shows the scatter plot for IQ and time to complete the course for all subjects with IQ's below the mean, including the five subjects who did not complete the course because of slowness.

Just by chance, the four subjects with transformed* IQ's of less than 30 were assigned to the book group. Because the regression of time to completion on IQ indicates that the mean time to completion for the group with IQ's less than 30 would be greater than the 77 hr allowed for completion, it is assumed that the failure to finish for the three out of four subjects in this group can be attributed to low IQ's rather than to their using books. Also shown in Fig. 2-3-4 are the two subjects who did not finish but whose transformed IQ's (37 and 42) would predict that they should have finished. It should be noted that one of this pair worked on books and one on a machine.

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*Transformed IQ's were obtained by subtracting a constant from standard Otis IQ's.

Table 2-3-2 shows the mean comparisons between books and machines for the two predictors and three criterion variables. It can be seen that aptitude was slightly lower in the book group but prior knowledge of the course material was somewhat higher. As for the criterion variables, average times to completion were identical, and the small differences on the two criterion tests were in favor of the book group.

Table 2-3-2. Mean Comparison of Books Vs. Machines

Variables	Books	Machines
Predictors		
Aptitude (Otis)*	49.3	50.8
Knowledge	21.1	17.6
Criteria		
Time	51.0	51.0
Facts	54.0	52.3
Concepts	57.7	56.9

*Standardized with Mean of 50

The magnitudes of the correlations between the predictors and the criterion variables ranged between 0.47 and 0.68. Toward the end of providing every opportunity for the null hypothesis to be rejected, a multiple covariance factorial analysis was performed for each of the criterion measures and adjustments were made for both of the predictors. The analysis was done with factorial partitioning of variance for cities and classes within cities so as to remove these sources of variance from the error term. The resulting comparison of adjusted means is shown in Table 2-3-3. None of the values of F for the book-vs.-machine comparisons was larger than 1.0, so the null hypothesis remains tenable for each of the criterion variables. Books and machines can be viewed as equally efficient with respect to costs in student time

Table 2-3-3. Group Means for Criterion Measures Adjusted for Multiple Covariance in Otis Scores and Prior Knowledge

Criteria	Books	Machines
Time	50.96	51.01
Facts	53.38	52.78
Concepts	57.22	57.28

and output in factual knowledge and/or conceptual facility under the conditions of this evaluation.

The principal implication of the study is that, for operational conditions approximating those of the present evaluation, variables other than student time and instructional effectiveness should be used in deciding between machines and books for programed instruction. Such variables would be cost, preference, administrative covenience, etc.

* * *

This article is based on a paper presented to a meeting of the Midwestern Psychological Association at Chicago, May 6, 1961. The authors wish to acknowledge the valuable assistance of George S. Rotter of Bell Telephone Laboratories, who performed the data analysis.

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Roe, A., et al. (1960) Automated teaching methods using linear programs, Automated Learning Research Project, Department of Engineering, Univ. of Calif., Los Angeles.

SECTION 3. Military Programs

United States military organizations have contributed a great deal to the field of programed instruction. Much of the basic research for this field has been done by the military or under military contract. Also, many of the existing programs, machines and simulators have been developed under military auspices. The work of the military in the field of programed instruction is of particular interest to those concerned with industrial training problems and academic education because the totality of military education encompasses both of these areas. This chapter is also of particular interest to those investigating the military as a possible market outlet for machines, programs, and services.

The first article of this section is an overview of the needs, research, development, and other activity of the military in the programed instruction area. Of particular interest is the breakdown of the different organizations within the military and their interest and/or contributions to the field of programed instruction. This article presents information on the nature of the activities in different military organizations and on where further information can be obtained on these activities. Virtually all types of training activities, from verbal learning to manual skills, are included in the organizations treated in this article.

The short article by Col. Hosmer and Capt. Nolan presents data on the training time saved by the use of programed instruction for courses in air-police training, medical training, and personnel training. Those interested in the feasibility, time, and monitoring economy of training will be interested in this summary of concrete practical applications of programed instruction for military training purposes.

The next article in this section presents an example of one type of system used to teach Russian to potential prisoner-of-war interrogators. This article has been selected for inclusion in this section because it is a typical military training problem with an exemplary system designed to solve the problem.

"Teaching machines in the modern military organization" is a theoretical paper that discusses the areas of the potential use of various types of devices. Descriptions of these devices are given, and some of the support and implementation problems are discussed.

The four articles that constitute this section are by no means the totality of work done in the field of programed instruction in the military. In the opinion of the editors, however, these articles are representative of the work done by the military, and the reader is urged to consult the bibliography in the article by Bishop and Ragin for more information.

Programed Instruction in the Armed Forces—an Overview

By C. K. BISHOP and J. J. REGAN
U. S. Naval Training Device Center

Training of and by the armed forces has always been sensitive to educational innovation—a good deal more sensitive than the educational community at large. This is due to a variety of factors. First, the objectives of military training are relatively well defined, since the behaviors or skills to be developed have been rather specifically identified. The range of skills required is more circumscribed than are those of secondary and higher education in the civilian community. Armed forces training has been principally concerned with perceptual-motor and procedural tasks. Additionally, since military training is more directive and less encumbered by formal diploma requirements, the reaction time for change is reduced. Anew idea or teaching device can be tried out systematically while still in the embryo stage. Finally, the need for shortening training time and improving quality has increased continually since World War II. The pool of qualified manpower is shrinking, the length of service is short, and the complexity of military systems is increasing at an amazing rate.

Since the climate for innovation is favorable and the need for maximum efficiency in training crucial, the military services support a substantial effort in educational research both in their own laboratories and through contracts to universities and industry. The Army, Navy and Air Force all support important programs of educational research.

This research and development has led in pilot training, for example, to the successful use of flight simulators a decade before their introduction into nonmilitary training. The armed forces have pioneered in the development and exploitation of audio visual aids, and their integration into the curriculum is today more advanced than in public education. The overhead projector, for example, now widely available commercially, was developed by the U.S. Naval Training Device Center. Again, in the area of educational television, the Navy was conducting controlled experimentation in its validity for training and had an operating, experimental TV facility in 1951. Comparisons were made among TV instruction, films, and "live" instruction (Rock, Duva, and Murray, 1951). It should not be surprising to learn then that, in the "dark ages" of programed learning that existed from the time of Pressey's first promulgation to the Skinnarian renaissance, various individuals working with and within the military were experimenting with this type of teaching (Fry, Bryan, and Rigney, 1959).

The purpose of this chapter is to describe those features of military training which make programed learning particularly useful and important, and to cite illustrative examples of military contributions and current research in automated teaching.

MILITARY TRAINING

Something was said in the introduction to this article of the features of armed forces training which give rise to and permit a special interest in educational innovation. Much of this applies to programed instruction—an innovation of widespread interest and importance to the entire educational community. There are, however, some special conditions that obtain in military training that make programed instruction of particular interest. These conditions can be described under the headings of personnel and subject matter.

Personnel

Personnel problems are twofold—instructors and students. These are admittedly universal problems, but they assume a proportion in military training which makes programed instruction especially desirable and useful.

Instructors in the military tend to be subject matter specialists rather than teachers as such. They are drawn from various technical fields and characteristically have little teacher training. Their competence is restricted to specific technical areas where they are, indeed, experts. This fact, combined with the character of the subject matter and the extremely limited time available, requires a highly organized and structured curriculum. Instruction proceeds according to detailed hour-by-hour study plans.

Instructor teaching loads are heavy even by present day public educational standards. Instructors are rotated in and out of teaching assignments so that no stable pool can be maintained. Release from military service, promotions and enticements from industry all act to augment the problem.

Since one of the effects of programed instruction is to standardize not only course content but, more important, to standardize the way in which such content is presented, it is obvious that such a technique would prove particularly useful in military training.

Subject Matter

Course content in the military is typically highly technical. With the increased emphasis on mechanization in all branches, technical "know-how" is a prerequisite. Not only must theory be taught and learned, but also considerable skill in operating, maintaining, and troubleshooting equipment must be acquired.

Whether it is sound pedagogy or not there is a dichotomy between the "nice-to-know" and the "must-know" courses. The shortness of time available for classroom instruction, the needs of the field for skilled technicians, and the rapid turnover in personnel compel the military to teach the minimum amount of material that must be learned. Furthermore, the program must be accelerated so that the enlisted student is cramming material eight hours a day, five days a week and often for eight to ten weeks at a time. In addition to the heavy classroom load, the student must also do extensive "homework" assignments each evening. It is not unusual for such courses to continue for 18 to 20 weeks on this type of schedule.

With such a concentrated time schedule there is little or no opportunity for remedial work or special help for the student. Even if the student is learning at a satisfactory rate there will be problem areas which are difficult for him to master. For example, in the field of basic electricity the concepts of resistance, reactance, and capacitance may be particularly troublesome. Well-constructed programs of self-automated tutoring can provide the student with the necessary information to help him overcome difficulties in these areas.

Because of the lack of instructors and as a result of the poor preparation many inductees have received in secondary education, a backlog of students frequently accumulates before there are classes available to admit them. During those weeks while the students are awaiting class assignment, self-automated tutors with programs pertinent to the school could be given as refresher courses. Considering the great heterogeneity of the incoming classes, it is especially important that at the start of a course the enrollee be brought up to a minimally acceptable level for efficient learning to occur. Such programs, of course, require no instructor and they efficiently utilize the student's time.

A kindred problem facing the military is the maintenance of skilled performance on those complex systems that are never activated except in times of national emergency. Some of these systems are so critical that little or no practice is possible and the only available training is at training centers which use expensive and complex training simulators. Maintaining highly complex skills over extended periods of time with no opportunity for practice is difficult. It is possible that appropriate teaching machine programs for maintaining such skills can be devised. Although the intricate problem of transfer of training is involved here, it should be pointed out that those skilled performances which consist of motor acts, i.e., muscular activity, are rarely purely "motor." There are verbal components in any acquisition of a muscular activity. Under the conditions mentioned here there is no reason why practice on the verbal aspect cannot be effected. Also, there is ample evidence that pictorial representations of stimulus objects can lead to high positive transfer (Gagne, 1958). In other words, under certain conditions there is little loss of transfer if one learns from pictures rather than from the real object. This concept of stimulus similarity and also the verbal components of a skill could be presented with teaching machines, and since the aim is to maintain associations that have already been learned, the transfer should be high. Automated tutors of the Crowder type could well be used in these situations. Not only could procedures training be maintained, but appropriate pictorial representations of relevant malfunction displays could be shown and the student interrogated as to the proper course of action to be taken.

Continuing with the same line of thought, learning and maintaining troubleshooting skills for those systems can be done with machines. Frequently, the troubleshooting process is largely an intellectual activity, namely, that of problem solving and examining the cause-to-effect relationship. Conventionally, troubleshooting and data flow are taught through a student and a skilled instructor on actual components of a particular system. The rub, once again, is the availability of instructors and equipment. An automated tutor, however, can be made to simulate the equipment and the instructor insofar as the information input to the student is concerned.

Even the nonverbal aspects of perceptual-motor behavior can be developed through programmed instruction. "Adaptive" machines such as those envisioned by Pask (1960) can program inputs (stimuli) to the student as a function of his behavior. As the students acquire skill the values of the dimensions of the system can change, approaching the "real life" situation.

The subject matter of military training, then, since it tends to be concrete and factual and since it must be presented in highly concentrated form, is particularly suited to programing. The need for and feasibility of automated instruction are clear. The balance of this chapter will be devoted to a description of representative research and application efforts by the military services.

STUDIES IN PROGRAMED INSTRUCTION

The development and application of programed techniques are proceeding in all three services with particular attention to those areas where special problems exist. Continuing interchange of information and materials takes place among the services although actual studies are conducted independently. Each branch, of course, while involved in various aspects of automated teaching, has its own emphasis.

Army

Electronics training is one of the major problem areas in all the services. The requirement for skilled electronics personnel is increasing daily both in quantity and quality. One of the Army Technical Services (the Signal Corps) conducts a substantial amount of electronics training for the Army. The School Text Division in conjunction with the Education Research Division at Fort Monmouth, New Jersey, is programing 32 hours of the fundamentals of electricity. This will be a linear program. Plans are being made to compare this program with conventional methods. A similar effort is also underway at the Southeastern Signal Corps School at Fort Gordon, Augusta, Georgia. This latter program, also linear, is concerned with communication procedures.

The Army Rocket and Guided Missile Agency has been sponsoring programed instruction research at the Electronics Research Laboratory of Columbia University. They have compared programed instruction with reading manuals and reading statements in the area of missile fire control orientation (Robinson, 1961).

Several studies are being conducted by the Human Resources Research Office (HumRRO) of George Washington University. A course in Russian specifically directed to military needs has been programed. This group is also working with the Signal Corps in programing maintenance material. Finally, the Human Factors Division, Chief Office of R&D, U. S. Army, is participating in studying the integration of programed learning with closed-circuit television.

Navy

The Navy has placed primary emphasis to date on investigating experimentally certain variables associated with programed instruction. A number of programs have been prepared in electricity and mathematics principally for the purpose of investigating these variables. In addition, at least two field applications of programed learning are currently undergoing test.

Office of Naval Research. The Office of Naval Research is sponsoring several studies designed to contribute to the theory and application of programed learning. This agency is supporting, on a continuing basis, basic research at the University of Southern California and at the American Institute for Research.

Although ONR's interest is primarily theoretical, a study is being made by the University of Southern California in troubleshooting and refresher training. At Treasure Island, California, the learning of troubleshooting by either a scrambled book or by a linear program is being evaluated as a substitute for laboratory experience. These two techniques are also being evaluated for refresher training by shore-based personnel prior to their return to the fleet.

Naval Training Device Center. Another naval agency besides ONR that has been actively engaged in research is the Naval Training Device Center. From 1956 it has been investigating such variables as the nature of context cues (Silverman, 1960a), randomness versus sequential presentation (Zuckerman, 1961), response mode, pacing, and motivational effects (Silverman, 1961), and a preliminary field validation study at a naval school.

At the time of this writing a field validation study in the use of programed learning is being conducted at the Service School Command, Great Lakes Training Center. The contractor is Teaching Machines, Inc., supported by the U. S. Naval Training Device Center. Programs have been developed in DC and AC electricity for the Navy's Electricity and Electronics Preparatory School. In addition, a course in the calculus for electronics has been constructed for an advanced electronics school. Since many enlisted men have poor preparation in the basic operations of arithmetic, a refresher mathematics course has also been provided.

A cursory description of the experimentation to be conducted in the Preparatory School is as follows: The population from which the experimental and control groups will be randomly drawn consists of enlisted men chosen to be electronic technicians. Half of the experimental group will learn electricity with a teaching machine and the other half with a programed book. Control groups will consist of classes taught by the traditional lecture method and by closed-circuit television. All groups will be equated on GCT-ARI scores and the criterion tests will consist of the school's regular examination as well as an electricity test independent of the naval school.

Further implementation of this study will be conducted by the Personnel Measurement Research Branch of the Bureau of Naval Personnel who will replicate the first experiment with larger samples, investigate retention effects, and determine the relationship between individual differences and programed learning.

Other Naval Installations. A partial list of naval agencies either actively engaged in or having shown interest in programed learning are the following:

a. The Chief of Naval Air Technical Training at Memphis, Tennessee, who is currently developing programs in electrical courses relevant to their teaching needs.

b. The Bureau of Supplies and Accounts, Washington, D. C., which is contracting for programs in storekeeping and retail sales.

c. The San Diego Naval Base where experimental work is being conducted on the feasibility and utilization of branching programs in the teaching of electronics.

d. The Submarine School at New London, Connecticut which has put on board Polaris submarines mathematical programs developed by Harvard University. These programs, carrying college credit, are used in conjunction with teaching machines.

e. The Guided Missile School at Dam Neck, Virginia, which has assigned scrambled books on computer arithmetic in the learning of basic computer courses.

Coast Guard

The Coast Guard Academy at New London, Connecticut, is developing programs and using teaching machines.

Marine Corps

The Marine Corps at Quantico, Virginia, has evinced interest in the programing of foreign languages for refresher training of their officers who will be stationed at oversea posts. Currently, they are investigating the feasibility and utilization of various teaching machines and how they may be implemented by the Corps.

Air Force

The Behavioral Sciences Laboratory of the Wright Air Development Division is intensively conducting research. Some aspects of their program of research are the development of automated instructional programs and facilities, effective displays of information in training systems, effective ordering of information for automated training, assimilation of information during automated training, and motivational aspects (see the article by Eckstrand, Rockway, Kopstein and Morgan in this section). Historically, they have shown a marked interest in this form of teaching and several of the well-known names today in the field of programed learning developed their early interest through the research done in the Air Force.

WADD is sponsoring two programs at the University of Pittsburgh. One program is in the area of general science for junior high school students. Two different formats have been constructed, one a linear format and the other a spiral format. The second program on the university level deals with the mathematical bases for management decision making. This, also, is in two different formats, one on a single track and the other a multi-track version.

With the Educational Testing Service, WADD is also investigating the relationship of mental test theory and automated programs.

Keesler Air Force Base Project. The Keesler Air Force Base experiment in basic electronics is being continued after the completion of the preliminary experimentation (Benson and Kopstein, 1961). The automated material is intrinsically programed and ultimately there will be a three-way comparison of the effectiveness of the instruction using a machine, a scrambled book, and the conventionally taught course.

Other Air Force Installations. Agencies that are either actively investigating program learning or have shown a marked interest in the use of this type of instruction are the following:

a. The Air Force Academy at Denver, which is in the process of training instructors in the art of programing courses to be taught at that institution.

b. The Strategic Air Command, which is using a variety of programs for individual study at various sites.

c. The Medical Service School, Gunter Air Force Base, Alabama, which has evinced interest in the use of automated instruction for the training of medical technicians.

d. The Air Force Systems Command at Bedford, Massachusetts, which has been sponsoring the American Institute for Research for the investigation of self-instructional programs for SAGE system operators. The primary aim is to develop and evaluate automated tutoring techniques and materials as they pertain to the training of basic job knowledges and skills for command and control operator tasks within the SAGE Track Monitor and Intercept Director positions (Shettel, et al., 1961).

STATE-OF-THE-ART INFORMATION

In addition to the current efforts at programing and field tryout described above, the armed forces have produced under contract a number of critiques and summaries of the field of programed instruction. They include the following:

a. Two well-known studies sponsored by the Office of Naval Research: an extensive bibliography in teaching machines (Fry, Bryan and Rigney, 1959) and current trends toward the automating of learning and how they affect the Navy's technical training problems (Bryan and Rigney, 1959).

b. Carr, under contract with the Air Force, has presented an interesting selected review of the literature with emphasis on those studies that provide a functional analysis of teaching machines (Carr, 1959).

c. Four Air Force scientists at the Wright Air Development Division have clarified and explained the concept of teaching machines and its implication to military training problems (see article by Eckstrand, et al., in this section).

d. For the Army, HumRRO has sponsored an annotated bibliography in the automation of instruction (Darby, 1959, and Robinson and Fiegel 1961) have published a history, principles, and applications of teaching machines for the Army Rocket Guided Missile Agency.

e. A critical and analytical review of the state of the art in automated teaching has been prepared by Silverman under a contract to the Naval Training Device Center (Silverman, 1960b).

PROGRAMMED INSTRUCTION AND NONVERBAL BEHAVIOR

Although only passing reference has been made to earlier more basic research efforts (they are fully described in the referenced reports), they have been instrumental in the formulation of the programing and tryouts currently in progress. They have also opened up further areas of potential application in programed instruction. Among these is an extension of programed instruction alluded to in the introduction. The bulk of what has been discussed or referenced so far relates to verbal learning. However, an important class of skills required by the armed forces can be described as perceptual-motor (for example, vehicular control). There is a potential application and extension of programed techniques to this nonverbal behavior field through what might be called ''adaptive'' trainers.

The Ohio State University Aviation Psychology Laboratory, under U. S. Naval Training Device Center sponsorship, has been investigating tracking performance as a function of differing schedules (step sizes) (Briggs, 1961). The trainee practices in one tracking configuration until a given level of skill is attained, at which point the training device (self tutor) provides him automatically with a different (more difficult) configuration. The measure of success is the extent of complexity achieved in a given time. The Engineering Psychology Branch of the Naval Research Laboratory has developed a tracking device with such features.

A great deal of work remains to be done in this area. For example, which dimensions of the task should respond to trainee output and at what points in the training process should changes take place? The Office of Naval Research under contract to Dunlap and Associates is exploring the potential utility of such scheduling to problems of personnel selection and equipment design.

In the case of nonverbal auditory behavior, Bolt, Beranek and Newman, under contract to the U. S. Naval Training Device Center, is exploring the application of automated teaching principles to training auditory skills. A computerized research tool has been developed for this purpose.

OVERVIEW AND SUMMARY

The scope and intent of this article does not permit a complete or detailed review of the past, present and future of military research and development in programed learning. The authors have contented themselves with indicating the trend of present development and a listing of representative research programs. It is hoped that the reader will have sufficient data to explore more thoroughly those programs of particular interest to him. A few words are in order, however, concerning future trends.

It was contended (and, hopefully, demonstrated) that not only have the armed forces responded to educational innovation, but that they have done so with more alacrity than the field of education in general. In the area of programed teaching, however, routine application by the armed forces is proceeding in, if anything, a somewhat less accelerated fashion than it is in civilian quarters. This is due in part to the widespread impact of the technique on general education, the limited utility to the military of commercially available programs and the consequent burden of special program development.

In addition, there are many gaps in research information concerning the relative merits of such programed instructional features as kinds of programs (linear-branching), responses (constructed-nonconstructed; overt-covert), and influence of various kind of subject matter. These gaps even extend to the value of automated instruction itself as compared with more conventional instruction (Silverman, 1960b).

The supporting research programs of the armed forces will continue to attempt to close these gaps but, in part because research in educational methods is difficult to generalize, an increasing emphasis will be placed on the development and application of programs. This course will provide information on one of the major questions still facing researchers in programed instruction. That is, "What are the effects of such instruction when it is in long term use?" Will initial novelty effects be replaced by attitudes less propitious to the learning process? The continued use of programed instruction may well bring to light the utility of features not evidently important at present.

The trend in the armed forces is, then, one of cautious optimism. The research, development and application resulting from this trend should benefit both the armed forces and education in general.

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Time Saved by a Tryout of Automatic Tutoring

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The purpose of this research study was to analyze the results from the administration of a self-instructional device compared to traditional classroom teaching methods.

Military students in training in three separate courses were selected on a random sampling basis for this experiment. A scrambled book was prepared for a designated portion of instruction within each course and programmed after the Pressey method of the multiple choice problem solving technique.

Crowder type scrambled books were prepared by educational specialists in conjunction with instructors of the experimental hours to insure complete agreement of desired learning outcomes. A pretest and end-of-instruction test consisting of different items measuring the objectives of these hours were prepared and validated.

In each course, two control groups were given normal classroom instruction by prescribed lesson plans and two experimental groups were given the scrambled books. Experimental groups were also subject to any films, student literature, or performance projects normally given to the control groups.

One control group and both experimental groups were given a pretest while all groups were given the end-of-instruction test. All groups were readministered the end-of-instruction test at eleven to thirty-eight days later to measure retention of learning.

No observable Hawthorne effect was noted for the groups which were pretested as compared to the excepted control group. Students learning via the scrambled book finished in much less time than was allotted for normal classroom instruction.

An analysis of results (see Table 3-2-1) showed students in experimental groups gained a comparable amount of academic learning in less time than students in the control groups. No major differences were evident between groups on the end-of-instruction test given to measure the retention of learning outcomes.

An analysis of student achievement by general aptitude revealed no major differences between control and experimental groups. Students with higher aptitude gained more than those of lower aptitude; however, gains for students of both high and low aptitude were greater than in normal classroom instruction.

Table 3-2-1. Automated Tutoring Statistical Results

Group	Cases	Pretest mean score (%)	Post test mean score (%)	Pre/Post test diff. (%)	Retention test mean score (%)	Post/Ret. test diff. (%)	Mean time (min)
Department of Air Police Training							
Control 1	58		69		64	—5	180
Control 2	63	55	63	8	67	4	180
Exp. 1	68	59	73	14	66	—7	57
Exp. 2	57	58	70	12	67	—3	47
Department of Medical Training							
Control 1	58		62		48	—14	180
Control 2	58	23	62	39	52	—10	180
Exp. 1	51	29	62	33	52	—10	110
Exp. 2	55	26	62	36	48	—14	110
Department of Personnel Training							
Control 1	27		76		80	4	420
Control 2	30	41	80	39	79	—1	420
Exp. 1	17	45	86	41	80	—6	200
Exp. 2	21	41	76	35	79	3	200

Analysis of data for the approximate one-third of the students in the experimental groups who finished first versus the approximate one-third who finished last showed that the slow-pacers learned as much as or more than fast-pacers.

This experiment was restricted in scope and its findings merely establish a trend; however, it appears that students learn effectively in less time by the scrambled book self-instructional device.

A Feasibility Study of a Special Machine-Taught Oral-Aural Russian-Language Course

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Can speaking and understanding a foreign language be effectively taught without benefit of a human instructor? An opportunity to find the answer to this question arose when we were asked to develop a special oral-aural language course, based on a limited vocabulary, for obtaining tactical information from Russian-speaking personnel.

The effectiveness of this course, as measured by the ability of the students to adequately speak and understand the limited Russian course material, supports the feasibility of machine-teaching limited language courses. The possibility of machine-teaching a full-scale foreign language is also supported by this research. This concept of limited language, with the general format of question frames and inserts plus classes of the most probable answers, could be applied to achieve economy of training time in other situations in which there is a need for some, but not complete, foreign language ability.

THE PROCEDURE

For purposes of a pilot study to determine the feasibility of such a completely automated course, content was selected from military literature. This content, first drafted in English, consisted of 16 commands such as "surrender," "hands up," and "speak slowly," 10 question frames such as "have you there...," "how many...," and "where...;" 100 terms such as "tanks," "men," and "guns" that could be meaningfully inserted into most of the question frames. In addition, 100 basic answers were composed of words that might be used by a prisoner in answering these tactical questions. These were words such as "yes" and "no," cardinal and ordinal numbers, compass headings, time divisions, etc., plus the necessary connectives. Answers were formulated so that the words used could be interchanged to make up other probable answers. The total vocabulary consists of about 450 words. The course objective was to teach the students to give the commands and ask the questions in Russian and then to translate the related Russian answers into English.

Programing the course material was the heart of the research. The procedure of arranging and sequencing the course material in a manner calculated to duplicate the functions of human instructors, maximize learning efficiency, minimize learning time, and maintain motivation was based on a review of previous research and classroom observation. Programing was done in the following five major steps:

1. The English course material was translated into Russian, using the spoken rather than the written language as the major guideline. Each utterance was translated to achieve comparability of word order and equality of word number.

2. The course material was divided into three sections to facilitate mastery of pronunciation by first learning to understand the material that later was to be spoken, to provide a logical framework for exposure to continued repetition of material by using the same material in all three sections for different purposes, and to permit the use of the student's native tongue and, thereby, letting the student enter immediately, directly, and successfully into learning a foreign language skill. The first section consisted of understanding the questions and commands or translating the Russian into English. The second section consisted of speaking the questions and commands or translating English into Russian. The third section consisted of understanding the answers or translating the Russian into English coupled with asking the questions in Russian. The material of each section was programed into lessons using the principles of graduated difficulty and meaningfulness of material. Graduated difficulty was achieved by selecting material based on the amount or length of utterance and similarity of the Russian to the English. Meaningfulness of material was achieved by presenting the material, for the most part, in the form of a complete command, question, or answer.

3. The lessons were composed of items defined as any command, question, or answer or any part thereof. The basic programing procedure for the items was derived from the method of paired associates and straight translation. Essentially, this consisted of a presented stimulus, either Russian or English, a response interval during which the student can make a response either in English or Russian, and presentation of the correct responses, either English or Russian. The items of each lesson were programed using the principles of decreasing assistance, or cue drop-out, and varied repetition. Cue drop-out was attained by arranging each lesson in five lists that contained identical material in various orders. The first, or direct-cue, list completely gave away each answer or response. The second and third lists gave progressively fewer cues to each answer. The fourth and fifth lists gave no cues to the answers. Varied-repetition was attained by presenting identical items two or more

times in a list or by presenting identical parts of items two or more times in a list.

4. Printed panels prepared for every lesson presented detailed instructions, limited samples of list construction and occasionally a brief note of linguistic interest. On the opposite side of each panel was the score sheet for that lesson. A legal-sized clip board lined with corrugated cardboard was used to hold a score sheet. The students used metal styluses to punch holes in their score sheets to indicate the successful or unsuccessful outcome of each of their individual responses in every lesson.

5. All lessons were recorded on master tapes. Five copies of each master tape were made and put into cartridges to make five complete nets. There were 82 tapes in one complete set excluding seven test tapes. There were 65 lesson tapes, 16 review-preview tapes, and one pronunciation tape. The major problem in recording the master tapes was in timing the student response intervals. These are empirically fixed at a time in which the correct response, if known and spoken at the normal rate, could be given twice. Dual-track language-teaching tape recorders that were modified to handle the tape cartridge were used in conjunction with earphones and a microphone attached to a flexible stand.

COURSE ADMINISTRATION

This Russian course was given at George Washington University using five small classrooms. Each of these small rooms contained a table, chair and electrical outlet. The taped-lesson library and a monitor's desk were located in the hall next to these rooms.

The course was administered twice, each time to five students. The first administration was a shakedown of equipment and procedures. Taking advantage of the shakedown experience, appropriate changes were made and incorporated into the course. The second administration was conducted with the students administering the course to themselves without interference by the experimenters. What follows concerns only the second administration and its results.

The five students taking this course were enlisted men in the U. S. Army who had just completed their basic training. These men ranged in age from 18 to 23 and in education from the 11th grade through college. None had any previous Slavic-language experience. Their language-aptitude-test scores, as compared with college freshmen, ranged from the 10th to the 65th percentile.

In the beginning, the students were given a language aptitude test and a brief orientation. Then, each man was assigned one of the small rooms and specific equipment. After he set up his equipment, he read his instructions and study guides, picked up the first tape cartridge lesson with its panel, and started to work. When he finished the first lesson, he replaced his recorded cartridge, and put his punched score sheet on the monitor's desk. He then selected his next lesson and the process was repeated. After the first day the procedures were identical except that each morning the student selected a review-preview tape that covered the material of the preceding day. After going through this tape once he returned it to the tape library, took out his next scheduled lesson, and so on.

There were two methods of keeping track of what the students did on each lesson. First, the students' verbal responses or answers were recorded on the lesson tapes. If all the items in a lesson were answered correctly, the tape was kept as a permanent record. If some of the items were answered incorrectly, the student repeated the lesson, automatically erasing all of the old responses and recording his new ones. Lessons were repeated in this way until all the items were answered correctly.

Second, the student punched a hole in an appropriately marked place on the score sheet to designate each response he made as correct, partly correct, or wrong. A non-Russian-speaking member of the research staff sat at the monitor's desk. He inspected the punched score sheets for evidence of gradual acquisition and mastery of the material. This monitor also recorded the time the lessons were taken out and returned and any rest pause that occurred while the student was working on the lessons. There was practically no interaction between the monitor and the students.

Every student took a self-administered tape test after each section and, at the end of the course, a final tape test that covered all of the course material. A simulated interrogation test then was given, with the students questioning native Russians.

THE RESULTS

Working about 6 1/2 hr a day, all five students completed the course in about 23 days. Course completion times ranged from 22 1/2 to 24 days. In the final tape test covering all of the course material, the spoken Russian of all five students was first scored by a native Russian expert on the research staff. Each student was then re-scored on the adequacy of his speaking ability by other native Russian experts. These experts, four in number, are professors of Russian at the U. S. Navy Language School in Washington, D. C. Prior to the time they scored the tape, they had never heard the particular student speak Russian. The scoring procedure consisted of listening to the student's spoken Russian and writing down the English translation if the Russian was understandable. An over-all evaluation of each student's pronunciation also was made.

Total test scores ranged from 90 to 93% correct. Scores on speaking Russian ranged from 86 to 93% of course material correctly spoken with evaluations of pronunciation ranging from fair to excellent. Scores on understanding the Russian ranged from 89 to 93% correct.

The simulated interrogation test consisted of the students questioning native Russians. Each student was given a stack of cards with an English question on each. He translated the questions into Russian, heard the native Russian's answer, and translated this answer into English. The native Russian had been given a story, written in English, of a fictitious situation. From this story he composed the answers he gave in Russian to the student's questions. In this simulated questioning situation, the five soldiers obtained from 85 to 97% of the possible information given by the Russians in answering the questions.

DISCUSSION OF THE RESULTS

All experimentally administered courses that result in favorable acquisition and usability scores must face the criterion of producing comparable results when given under non-experimental conditions. The overall construction or programing of this limited Russian-language course into sections and lessons definitely structures the learning task, provides reasonable and definite subgoals, and a clear and achievable terminal point. The specific programing of the lessons to assure successful responding and continual reinforcement seems to produce and sustain a high level of student motivation.

On the basis of these factors the prediction can be made that if this course were administered under nonexperimental conditions to students of equal aptitude, the results could be favorably compared with those recorded in this experiment. Further support for this prediction is derived from the fact that the experimental course was completely automated. This means that the precisely standardized lesson material will be presented in exactly the same fashion in any nonexperimental administration of the course. And in addition, replacing language instructors by tape recorders makes this standardized lesson material available for repetitive practice on a basis that can be achieved only by the use of machines.

* * *

The research reported here was conducted by the authors while they were employed by the George Washington University, Human Resources Research Office, operating under contract to the Department of the Army. Opinions and conclusions are those of the authors and do not necessarily represent views of the University or the Department of the Army.

Teaching Machines in the Modern Military Organization

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Teaching machines have aroused a great deal of interest recently in various professional and scientific fields. Appropriately enough the military psychologist has been among the most interested in this new technology. Training has always been one of the factors of vital importance to efficient military operations and in recent years has definitely become big business within the military. Within the U. S. Air Force, for example, it is conservatively estimated that over one billion dollars was spent on training operations during the past year. Consequently, military psychologists have devoted considerable effort to developing techniques, methods and devices for improving the efficiency of training. It is small wonder, therefore, that the teaching machine or automated training device has attracted the attention of the military psychologist early in its developmental history and has set his imagination racing. For these self-instructional devices hold out the promise of solving, or alleviating, a number of the problems that have beset military training.

Already, three names have been used in this paper to refer to the topic under discussion—teaching machines, automated training devices, and self-instructional devices. These are the terms most commonly used, but there are others, and this diversity of nomenclature reflects both the newness of the field and the variety of special meanings which teaching machines have for different persons. Regardless of the terminology used, or the special interests of particular investigators, these devices constitute a class of instructional media with unique characteristics which differentiate them from other media. Throughout this paper, the three terms listed above will be used where each seems most appropriate.

THE TEACHING MACHINE

Teaching machines are devices which provide effective instruction to a student or trainee without the direct participation of a human instructor. In other words, these devices simulate in one manner or another the functions normally fulfilled by a human instructor in individualized teaching or training. Their functions can be categorized generally as follows:

a. Presentation of information. Some machines present informational material by a display which is part of the device itself. Other machines depend upon supplementary sources of information such as textbooks or other adjunctive displays. In either type the information presented is the material to be learned and provides the background for the next function.

b. Presenting questions or problems. All self-instructional devices present the student with questions or problems to which he must make some active response. The questions or problems posed are keyed to the information which has been presented to the student for mastery. In some devices, functions a and b are combined. The information to be communicated is actually contained in the questions or problems which are presented. This purely Socratic method of instruction has been used with considerable ingenuity in some devices and more will be said about this technique later.

c. Accepting and evaluating responses. As mentioned above, self-instructional devices require active responses on the part of the learner. In certain cases he selects his response from among alternatives which are presented to him, and in other cases he must construct his responses. All self-instructional devices also include some system for evaluating the student's responses against a criterion of adequacy.

d. Providing reinforcement. Closely associated with the function of evaluating the student's response is the function of informing the student of the adequacy of the response. This information, or knowledge of results, may be indicated by a "right" or "wrong" signal of some kind or may come from the student's own comparison of his constructed response with a standard. In any case, the prompt and clear presentation of knowledge of results is a consistent feature of self-instructional devices. In some cases a distinction has been made between knowledge of results and reinforcement, the argument being that confirming the correctness of a learner's responses to problems may be expected to be reinforcing only if the learner's motivation is intrinsic to the task being learned (Carr, 1959). Self-instructional devices are well suited to extrinsic reinforcement also, but this problem has not yet been carefully analyzed.

e. Programing learning. Self-instructional devices present material to the student in a manner and sequence intended to provide for efficient learning. The preparation and ordering of the blocks or "frames" of information to be presented by a teaching machine is called programing, and in all but the most complex devices, this function is performed by a human. Many self-instructional devices, however, are designed so that they can modify their program in a manner indicated to be desirable by the students' responses to questions or problems. Such a capability is called adaptive programing. The degree of adaptiveness among devices varies from merely dropping out mastered items in a serial program to selecting or generating problem situations which are highly tailored to individual needs.

Self-instructional devices derive their distinctiveness from performing all of the above functions in teaching or training a student. Other teaching aids, such as books, charts, films, and graphics, merely present information to the student, while more complex training devices, such as procedures trainers and simulators, require the constant presence of one or more instructors to fulfill the full range of teaching functions. The teaching machine alone provides true self-instruction on a routine basis by simulating the functions of the human instructor through electrical or mechanical means. As such, it provides a unique, new tool for exploitation in education and training.

MILITARY TRAINING PROBLEMS

Teaching machines have a special attractiveness to the military psychologist because they seem so particularly adapted to certain challenging problems in military training. These problems and the relationship of self-instructional devices to them are discussed briefly below since the value of these new devices will have to be assessed in the setting of these practical circumstances.

Cost of Training

Military training is expensive. It is costly first of all because of the complexity and diversity of the jobs involved and because of the large numbers of trainees involved. In fiscal year 1958, for example, the Air Training Command of the United States Air Force (USAF) gave technical training to approximately 300,000 men in several thousand different formal and special courses at a total operating cost of over $800,000,000. Since the major Air Commands also do considerable training, these figures represent only a part of the training within the Air Force. But training is expensive for another reason. It is expensive because there is so little time over which to amortize the cost of training. A large number of personnel given initial specialized training by the military services are available for only a single enlistment (as short as three years in the USAF), and even those who remain in the service require frequent retraining due to the constant introduction of new weapon systems. For these reasons, the ratio of training cost to useful work time is high in military organizations. There are several ways of reducing this ratio but one of the most direct is to reduce the cost of training. As a consequence, the military is always in search of ways to increase the rapidity and economy of training. Self-instructional devices offer a number of interesting possibilities here which can be appreciated without elaboration; need for fewer instructors, use of standardized materials, better and more flexible use of available training time, and assurance that efficient training techniques are being used.

Individual Differences

Individual differences in ability to profit from instruction have always been a perplexing problem in education by anything other than a tutorial system. In military training, there is a problem of almost equal magnitude in spite of selection standards and aptitude testing. This problem, although by no means unique to the military, is accentuated by the requirement for extremely rapid training of large numbers of trainees. Self-instructional devices seem ideally suited to help alleviate this problem. These devices offer many of the advantages of individual tutoring without the attendant disadvantages of high cost, shortage of skilled instructors, etc. Automatic tutoring provides instruction paced to the needs of the individual student and can be adjusted to the trainee as he is at the specific moment. In this manner, each student moves through the instructional program as rapidly as his talents allow him.

Quality Control

Military training requires rigid quality control of the products of training. Normally, the only purpose of military training is to develop specific human performance required in various military jobs. The specific performance must be produced with high reliability if a military operational capability is to be assured. Once again, the characteristics of teaching machines give cause for optimism with regard to this problem. Because teaching machines constantly measure and evaluate the trainee's performance in using what he has been taught, the teaching machine assures the proper level of all skills and knowledges that are required. Since training ceases only when each trainee has successfully dealt with each block of instructional information, a uniform and highly predictable product (i.e., trained man) is produced. Hence, for operational planning, much greater reliance may be placed on obtaining personnel with the required performance capability.

Shortage of Instructors

The shortage of competent, experienced instructors is one of the most serious problems in military training. The etiology of this problem is complex, involving administrative factors and military tradition, as well as aptitudes of available personnel. Nonetheless, the problem exists and is a serious source of difficulty in most attempts to increase the effectiveness of military training. The self-instructional device is a natural solution to this problem and hardly requires elaboration. The use of automated training devices reduces the need for human instructors considerably. Because instructional material is centrally prepared, requirements for competence in those "instructors" which are needed in the field is also reduced. Therefore, such instructors as may be necessary will function more as proctors and will themselves need less aptitude and less formal training. Thus, a major barrier to improved military training is eliminated through the use of automated training devices.

Trainee Motivation

Motivation is frequently a special problem in the military training situation. This is particularly true where the trainee is merely fulfilling an obligation for military service and has no career intentions with respect to military service. These people, moreover, usually constitute a significant proportion of the manpower available, and it is incumbent upon the military to use them as efficiently as possible. In the absence of career motivation, special attention must be given to making training an interesting and rewarding experience. Although there is not much firm data regarding the motivational characteristics of teaching machines, experience to date indicates that they are well received by trainees and that this positive reaction persists over substantial periods of time. More attention will be given to this problem later.

These are by no means all of the military training problems to which machines are germane. Nevertheless, the discussion should be adequate to explain the interest and enthusiasm of military psychologists for this new technology.

So far, our discussion of automated training has been intentionally at a very general level. In the remainder of the paper, however, various aspects of this topic will be discussed with somewhat greater specificity. First, some representative automated training devices and materials will be described and briefly discussed. Next, some current problems and areas of investigation will be summarized and special attention will be given to some projects which have special relevance to the military uses of teaching machines. Lastly, some discussion will be devoted to possible uses of automated training devices in the military and to certain requirements which need to be met before these devices can be fully and effectively exploited.

SOME REPRESENTATIVE TEACHING MACHINES

A few years ago it would have been possible to describe virtually the entire population of teaching machines in the space we are now devoting to a "representative" sample. In fact, the proliferation of machines during the past two to three years has been so great that the "representativeness" of our sample probably is somewhat dubious. However, the machines selected for discussion do represent some of the major attempts to mechanize the instructional process.

Teaching-Machine Design and Programing Philosophy

In general, the term "teaching machine" is a misnomer. Most machines do not teach, they merely provide vehicles for the presentation of preprogramed materials in a fashion which simulates some of the functions of an individual tutor. Thus, the characteristics of specific machines depend not only on the nature of the skills or knowledges to be learned, but also upon the particular programing philosophy to be implemented.

At the present time, there appear to be three major approaches to the programing of verbal and symbolic materials. The first is the simple multiple-choice approach originated by Pressey (1926, 1927). This is simply a variant of the usual objective examination augmented by self-scoring features, which provide the student with immediate feedback concerning the correctness of his responses. Pressey did not intend that his self-instructional tests and associated machines replace textbooks and other information presenting aids. Rather, they are designed to complement the conventional techniques by identifying areas of weakness and guiding the student in remedial study and review. Pressey's major contribution to teaching machine technology is his early recognition of the value of mechanizing some aspects of the training process.

The second major approach to programing is that developed by Skinner (1958) and based in part, at least, on principles derived from his conditioning work with animals. His teaching machine presents the material to be learned in a fixed sequence and requires that the student's responses be constructed rather than selected from a multiple choice item. Another relevant feature is the "information distance" between successive steps in the program; it is so small that correct responding throughout acquisition is virtually assured. In addition to Skinner's contributions to the art of programing, he is largely responsible for the recent surge of interest in machine instruction.

The third major approach to the programing problem is the variable sequence, multiple choice technique developed by Crowder, who labeled his approach "intrinsic programing" (1959). His materials consist of units of information (usually a paragraph or less in length) followed by a multiple choice question related to the particular unit being presented. This approach differs from those involving fixed sequences, in that student's response to a given question determines the material that he sees next. Thus, if he answers a question correctly he is presented the next unit in the main sequence. On the other hand, if he makes an error, he is shunted to a sub-sequence which permits him to review the previous material and explains the nature of his error. Thus, the amount of material to which a student is exposed is automatically tailored to his ability. This type of programing, like many others, does not require a machine for presentation. In fact, one of its most popular applications is a printed form called a "scrambled book." A scrambled book differs from the conventional book in that although the pages are numbered consecutively they are not read in the usual order. That is, after the student selects a particular multiple choice alternative he then turns to the page whose number is listed next to his choice. If he was correct, the material on the page confirms his previous response and presents the next unit of information. If he was incorrect, the information on the page is designed to clear up his misunderstanding before returning him to the previous page to try again. Crowder's machines, to be described later, provide more flexible semiautomatic mechanisms for storing and "turning the pages" of intrinsically programed materials.

To date, the major approach to the programing of machines for psychomotor skill teaching is that proposed by Pask (1957, 1958). Pask's approach is unique in that the teaching program is not completely predetermined. Rather, the machine is designed to emulate an ideal instructor who is in continual interaction with the trainee. It is assumed that the machine instructor and the trainee are engaged in a partly competitive, partly cooperative game (Pask, 1958). At the outset of training the machine has very few built-in rules. The rules are developed during the course of play as the machine learns about the trainee and builds a model of his behavior which is used to adapt the training routine to his individual requirements. The basic control mechanism for accomplishing the tutorial functions in Pask's machines is a self-organizing computer that can be adapted to the teaching of a wide variety of job skills.

Pressey's Machines

Pressey is generally conceded to be the father of the teaching machine. In 1926, he described "a simple apparatus which automatically gives and scores a test, and which will also, automatically, teach—and teach informational and drill material more efficiently, in certain respects, than the human machine" (Pressey, 1926). This early device, similar to that shown in Fig. 3-4-1, can be considered the prototype for the multiple choice approach to machine instruction. Basically, the device consists of a window in which multiple choice or true-false items are presented, a set of four numbered response keys which the student presses to indicate his answer, and a counter for tallying errors. The device has two modes of operation—a test mode and a learning mode. In the test mode the student is permitted to make only one response to any given item. After each response a new item is presented. In this mode no indication of response adequacy is provided. In the learning mode, on the other hand, an item remains in the display window until the correct button is pressed. Only then does the next item appear. Thus, in this mode the student is given knowledge of results after each response. This device also possesses the capability of dispensing a candy reward when certain goals are met. A later machine designed by Pressey (Pressey, 1927) also incorporates a "drop out" feature. That is, the machine can be set to sequence through a given set of items one at a time until each item has been answered correctly on two, three, or four successive trials. As the selected criterion is

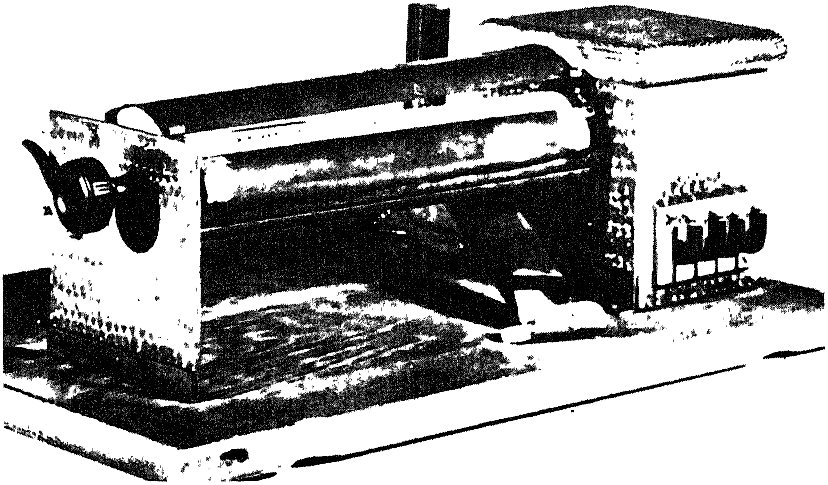
Fig. 3-4-1 One of Pressey's early machines

achieved for an item, that particular item is "dropped out" on subsequent trials.

Skinner's Machine

Most of Skinner's machines require that the student compose or construct a response rather than merely select one (ref. 17). The simple disk machine in Fig. 3-4-2 is probably the best known of Skinner's devices. In this machine, material is printed on 30 radial frames of a 12-in. disk. Each frame consists of a question or statement plus a correct answer. During the course of teaching, the statement only is exposed in the lower portion of a display window. The student responds by writing his answer on a paper strip beneath a second opening. He then operates a lever on the front of the machine which moves his response under a transparent shield and uncovers the correct response in the display window. If his response corresponds to the correct one he moves the lever horizontally. This punches a hole in the answer sheet opposite his response, recording his judgment of "correct," and modifies the machine so that this item will be skipped during subsequent presentations of the program. He then returns the lever to the starting position and a new frame is presented. The student continues to work through the program until all items have been answered correctly. When this occurs the disk revolves without stopping and the assignment is finished. Other constructed response devices have been designed in which the student com-

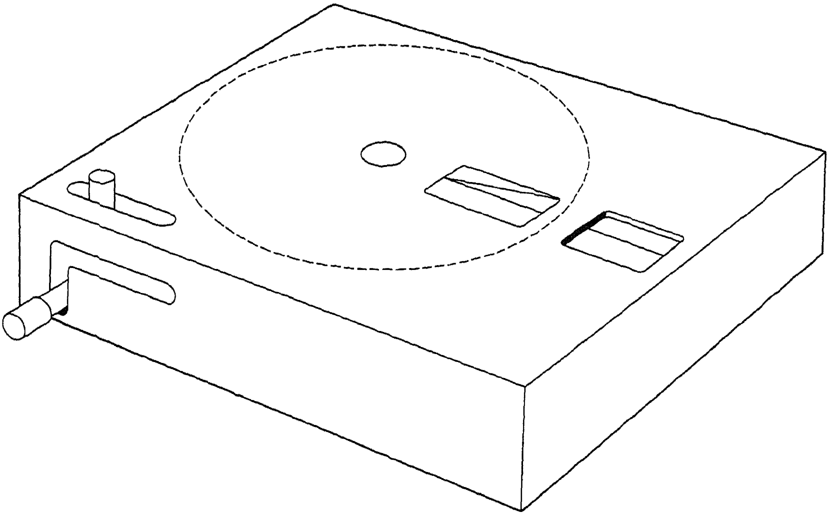

Fig. 3-4-2 Skinner's disk machine

poses his answer using a set of alphabetic and/or numeric sliders. The student's answer is compared by the machine with a coded response. If correct, the machine automatically presents the next frame. If incorrect, the student's response is cleared and he must compose another. The machine will not advance to a second frame until the first has been answered correctly. Not all of Skinner's devices require response construction, however. He has recently been experimenting with a series of preverbal multiple choice machines for use with young children (Corrigan, 1959).

The Subject Matter Trainer

The Subject Matter Trainer was developed by the USAF to provide an automatic means for teaching and testing certain kinds of technical information without the aid of an instructor (Besnard, et al., 1955a). This device has many features in common with Pressey's earlier machines. Each of 20 stimulus items is presented one at a time in a display window located on the left side of the panel, shown in Fig. 3-4-3. The 20 response items are mounted in a scrambled order on a plate at the right side of the panel. Coded answer plates are readily interchangeable to permit new orders for correct response items. Each response item is located between a response button and a green indicator light. The device has two digital counters for recording student performance. One counter advances one unit for each response made by the student while the other tallies only correct responses. A later model of the trainer also incorporates a "drop out" feature similar to that described for Pressey's machine above (Besnard, et. al., 1955b). The following six modes of practice are provided by the trainer:

a. Quiz mode. The name of this mode is somewhat misleading, since it is the machine and not the student that is being "quizzed." When a stimulus item appears in the window the student presses a "quiz" button which illuminates the green light next to the correct answer. Thus, the machine guides the student through the correct response sequence for the entire series of stimulus items.

b. Modified quiz mode. In this mode the "quiz" button is deactivated. When a stimulus item appears, the student is required to press the response button next to his chosen answer. If his selection is correct the green light next to his answer will glow, and the machine can be advanced to the next stimulus item. If he is incorrect, however, a red light glows and a buzzer sounds indicating an error. Simultaneously, the green light next to the correct buzzer sounds indicating an error. Simultaneously, the green light next to the correct answer comes on telling him what his answer should have been. The student then must depress the correct answer button before the machine can be advanced.

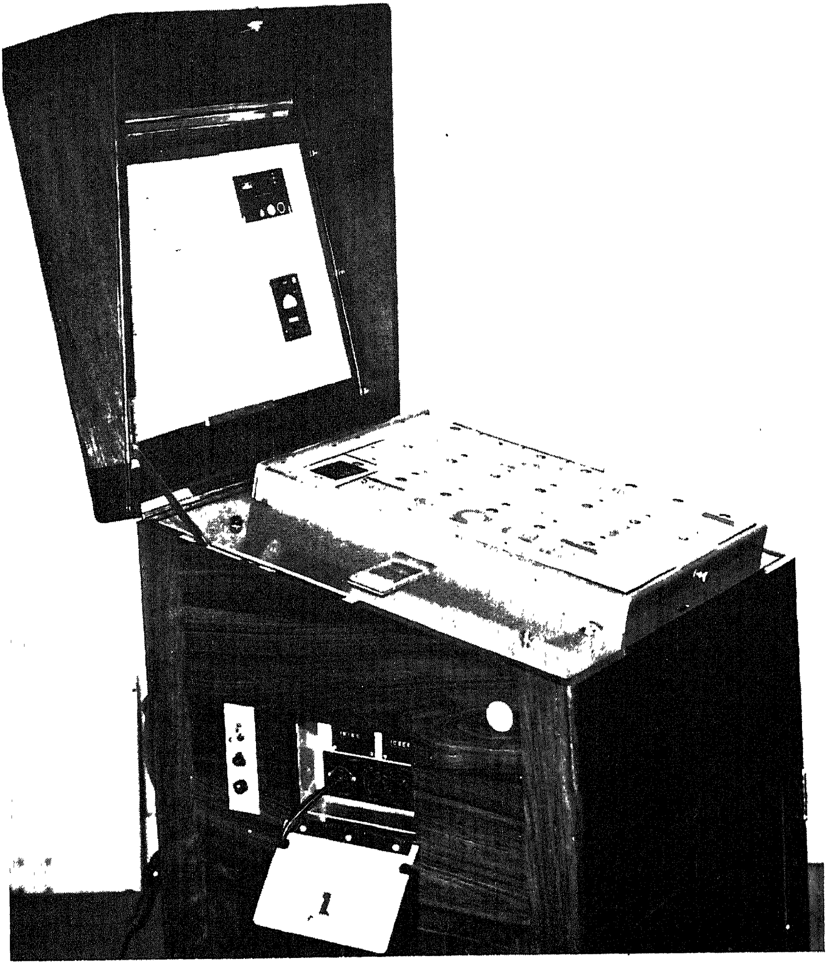

Fig. 3-4-3 The subject-matter trainer

c. Practice mode. This mode is like the previous one except that the student must continue pressing buttons until the correct answer is found. When the correct answer finally is selected, the corresponding green light will glow and the machine can be advanced to the next stimulus item.

d. Single try mode. In this mode the student is permitted only one response for each stimulus item. After each response he receives either a red or green light.

e. Paced practice mode. This mode is primarily for experimental use. It permits duplication of the "practice" and "single try" modes by an experimenter who controls the rate of appearance of new items.

f. Test mode. In this mode the student receives no feedback concerning the adequacy of his response. He is permitted only one response to each stimulus item before being required to go on to the next stimulus item.

Crowder's Machines

Two versions of automatic, random access, microfilm projectors have been developed for use with Crowder's intrinsically programed materials. An early prototype was developed a number of years ago by the USAF. This first version was called the Multipurpose Instructional Problem Storage Device, or MIPS. Recently, a much improved device was designed and fabricated under Crowder's direction at the Western Design Division of U. S. Industries, Santa Barbara, California (Crowder, 1959). This latest model, which is shown in Fig. 3-4-4, is known as the Western Design Autotutor. The program in the Autotutor is stored on 35-mm film, and both still and motion picture material may be intermixed. The advertised storage capacity of the device is 10,000 35-mm frames, although with a thinner film base this may

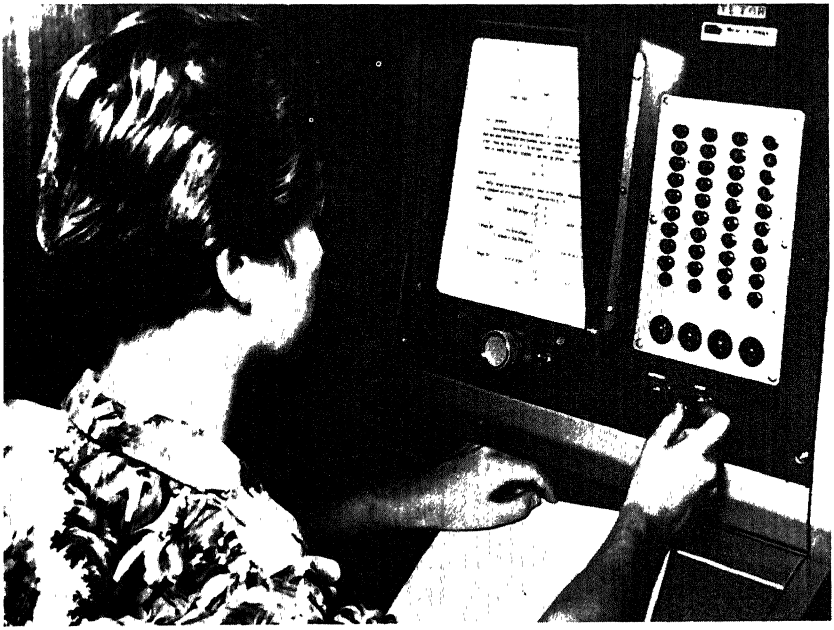

Fig. 3-4-4 The Western Design Autotutor

be increased to 30,000. In use, the student is presented with a unit of information on the viewing screen, along with a multiple choice question based on that unit. He then selects the next image to be presented by entering the number associated with the response he chooses into the selector buttons of the Autotutor. He next presses a "View" button, and the device automatically locates and projects the selected image. He then proceeds on through the program in the manner described previously. The machine can automatically record and print out on paper tape both the sequence of images viewed by the student and the time spent viewing each image, if such information is desired.

Pask's Machines

The most publicized of Pask's machines is the Solartron Automatic Keyboard Instructor or "SAKI" (Pask, 1958). This device was designed to teach the operation of a keypunch mechanism such as that used for punching IBM cards. As can be seen in Fig. 3-4-5, the major components of the system are a display unit, a keyboard unit, and a small self-organizing computer which controls the training routine and records errors. The display unit consists

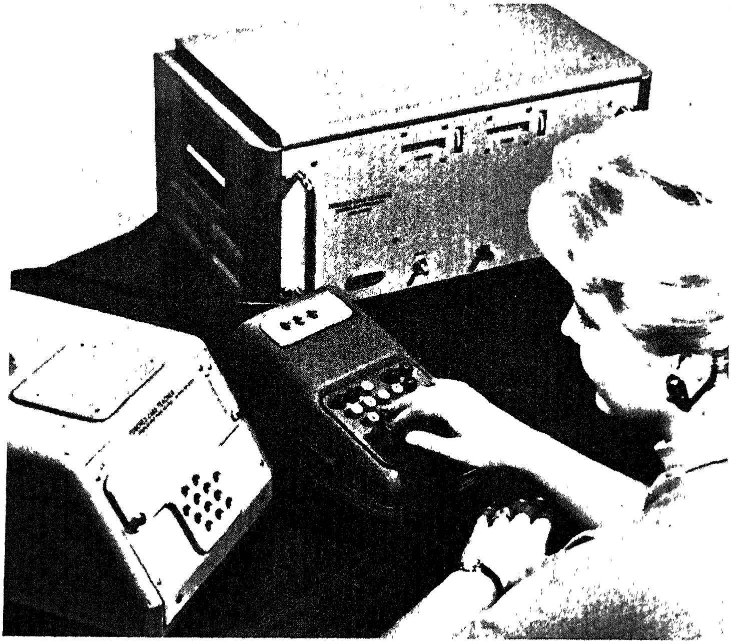

Fig. 3-4-5 The Solartron Automatic Keyboard Instructor (SAKI)

of a back lighted stimulus card with four lines of exercise material and an analog keyboard. Initially, the item to be punched by the student is indicated by illuminating both the appropriate figure on the stimulus card and the corresponding key position on the analog keyboard. During the early stages of learning the rate of presentation of stimulus items is relatively slow. However, as the student gains proficiency with respect to speed and accuracy, the rate of presentation of stimulus items progressively increases to a preselected maximum and the illumination of the keys on the analog panel gradually decreases to zero. Throughout training, the computer continuously adapts the stimulus program to the unique characteristics of the individual trainee. Other versions of this device are being developed for use with adding machine and typewriter keyboards. In addition to keyboard training, Pask has also investigated the use of a self-organizing computer in conjunction with a complex radar simulator for teaching pilots the tactical and maneuvering skills required in airborne interceptions (Pask, 1957). In this application, the computer (EUCRATES Mk 1) served the function of a highly skilled instructor in adapting training exercises to the particular needs of individual trainees.

PROBLEMS AND APPROACHES

On first impression it might seem that the diverse array of self-instructional schemes and devices would present diverse problems requiring an immense series of highly specific investigations. And, indeed, the first research on teaching machines was directed at some of the more specific and obvious issues. The initial research tended to investigate problems such as, whether to require a constructed response as suggested by Skinner (1958), or whether to allow a choice among multiple response alternatives; whether to present but a single series of items to everyone, or whether to have branching programs such as those used by Crowder (1959); whether to sequence the instructional items in such small "steps" that error responses would be virtually impossible, and so forth. Although some investigations of this type are necessary, a more systematic approach is desirable and seems to be emerging. Systematic programs of research should assure generalization of research findings to a wide variety of devices and materials to be learned, including both verbal and nonverbal tasks.

To maintain proper perspective about teaching machines, two facts must be recognized. First, teaching machines have no special or unique status in psychology. They are merely a specific example of the dynamics of teaching. The second fact to remember is that various authors and investigators apply their diverse and previously formulated viewpoints or scientific approaches to considerations of teaching machines. Because different authors have different conceptualizations of the teaching process, and even different philosophies of science, their approaches to teaching machines and their research are different, not to mention differences in terminology. Awareness of the basis for certain apparent differences should provide some perspective by which to understand and interrelate diverse sources of information about teaching machines.

Skinner's (1958) approach to teaching machines, and pertinent research influenced by his approach, quite naturally is consistent with his general approach to behavioral science. The research is pragmatic. Much of it consists of evaluating the effects of "programs" (sequences of instructional questions) prepared in accordance with a number of previously formulated principles. Sometimes the research implies as much about the ability of the investigator to practice the "art of programing" as it does about the principles of programing or any other conditions of the investigation.

A different approach to teaching machines is illustrated by Silberman and Coulson. Although they have not so stated, their approach, which emphasizes the statistical interrelationships among items in a program, is related to mental test theory. Gagnê and Bolles (1959) imply a still different approach to automated training. They conclude that the same factors govern the efficiency of learning whether the learning is controlled by a machine or by any other means. However, they also point out that, compared to traditional research on the influence of specific variables on the learning process, research on teaching machines is characterized by a much more intense search for the conditions that maximize the efficiency of learning.

Pask (1958) approaches teaching machines from the viewpoint of cybernetics and game theory. He conceives of the student and the instructor as two self-organizing systems engaged in a game which is partly competitive and partly cooperative. Pask, Carr (1959), and probably many others, including the present authors, believe that both the use of and research upon teaching machines must be guided by a functional analysis of the interactions among the learner, the material to be learned, and any type of teaching guide or "instructor." The "instructor" may be solely human, both human and machine, or solely machine. However, even a common point-of-departure such as a functional analysis of the instructional process will not counteract the effects of different theoretical or systematic viewpoints. We may expect diverse programs of research on teaching machines for many years to come.

SOME MILITARY USES OF AUTOMATED TRAINING DEVICES

So far in this article we have commented on the general relationship of automated training to military psychology, described some representative devices and discussed some current research issues and projects. Undoubtedly this material has already suggested numerous possibilities for applying automated training devices in the field of military training. On first impression, it would appear that there is no problem at all in thinking up all sorts of uses for these devices. Indeed, whenever an instructor is involved in a program of training, we have a potential for automating the functions of this instructor. But perhaps we are moving too fast; potential does not necessarily mean payoff. Contrary to much popular thinking, it is not always technically desirable to substitute machines for men. Rather, the assignment of functions to man and machines in a system should be based upon a careful analysis of the capabilities and limitations of each in relation to the functions that are required to produce the desired system output and, this is true regardless of whether the desired system output is lead pencils, bombs on target, or trained personnel. As Bryan and Rigney (1959) so nicely put it in their discussion of automated tutoring, "'The machines will save us' fallacy is so firmly rooted in current thinking that it may not be recognized in this new guide."

In other words, any discussion of the uses of automated training devices in military training (or any other training or educational program, for that matter) which attempts to become specific, must immediately come to grips with the following two problems: defining the role of the instructor in training programs of various types and assessing the comparative abilities of human instructors and machines in fulfilling these roles. These problems have not yet been carefully analyzed and studied. However, McKeachie (1959) has pointed out that teaching machines have focused the interest of teachers and research workers alike on these problems, and that the results of such interest may well improve human as well as automated instruction. Indeed, he feels that this may be one of the major benefits to be derived from the current interest in automated tutoring.

When a Machine Can Profitably Fulfill Instructor Functions

Rather than attempt a detailed analysis of the functions of the instructor, and then compare the ability of men and machines to fulfill these functions, we will discuss the military uses of automated training devices in certain extreme classes of instructional situations. Our discussion will be limited to cases where the instructor functions undoubtedly could be assigned with profit to a machine because the functions are too routine, the functions are too complex, or no human instructor is available.

Use of Machine When Instructor Functions Are Too Routine. In the first case, we are dealing with situations where it is advantageous to use automated training devices because the instructional situation is highly standard and routine. It will be apparent immediately that these are the same conditions under which it usually is profitable to introduce automation in industrial manufacturing operations. A little reflection will suffice to determine that a substantial amount of military training meets these criteria. Facts, nomenclature, and procedures must be memorized. Concepts and principles must be mastered. Data flow and component locations and interrelationships must be understood. A significant proportion of the time required for training in a military specialty usually is devoted to developing an understanding of a technical area, to serve as a basis for later skilled performance. In such cases the materials to be mastered are specifiable in advance and the criterion of mastery is unambiguous. The instructional task is that of presenting the material in a manner that will insure efficient mastery. Traditionally, this is done by having students sit in classrooms and listen to carefully outlined and frequently memorized lectures, study textbooks and manuals, participate in occasional recitations and drills, and infrequently take examinations. Delivering "canned" lectures, listening to recitations and drills and grading objective tests is a patently inefficient use of human instructors. In the first place, instructor personnel can be used more efficiently for work which cannot be done by machines and which requires more of their unique capabilities (e.g., determining what information the student needs to be taught and programing this material for effective learning). In the second place, inexpensive, automated devices can be designed which can probably out-do the human instructor in accomplishing the routine teaching functions mentioned above. Normal classroom instruction is heavily dependent upon passive listening and provides little opportunity for active response on the part of the student. It provides meager feedback to the student concerning his progress and relatively little chance for adjusting the pace to each individual's capabilities. The teaching machine, on the other hand, presents material in small amounts, provides for active response by quizzing often, delivers continuous feedback and adapts the instructional pace to the individual student. In short, the teaching machine seems almost ideally suited to this routine type of instruction. There will be problems in their use, of course, such as educating training personnel in their proper utilization, preparing subject-matter programs for the machines and integrating them into the existing training frame-work and concepts. Nevertheless, it can be said with some confidence that the effort will be well repaid in improved training and more effective use of available instructional personnel.

Use of Machine When Instructor Functions Are Too Complex. Sometimes, we are dealing with situations where the instructional task is quite the opposite from that discussed above; situations where the instructional task is too complex or too difficult for effective accomplishment by human instructors. Here again we have a counterpart in the industrial situation, where many complex data processing operations are handled by computers with a great consequent increase in efficiency. If it can be truly said that much military training involves the routine acquisition of knowledge and concepts, it is just as true that much military training involves the mastery of highly complex, extremely sophisticated skills both on the part of individuals and teams. Humans must be trained to monitor and control highly complicated machinery such as supersonic aircraft and aerospace systems. People must be trained to assimilate large amounts of information from diverse sources and make rapid decisions, as in missile count-downs. Teams of individuals must be trained to perform in an integrated manner in large data processing systems such as the USAF SAGE system. The skills involved in such operations are difficult to master and typically require long periods of intensive training involving much practice in realistic job environments. Historically, such practice was acquired in the job environment itself with an instructor present both for tutorial and safety purposes. Recent military systems, however, have been far too demanding on human skill to permit this approach completely; therefore, complex, ground simulators have come into vogue to aid in providing both transition and maintenance-of-proficiency training. As weapon systems have increased in complexity, so too have the training simulators, and these modern devices now have complex instructor-operator stations and require teams of instructors and trainer operators in order to provide realistic training sessions. Even so, the requirements for coordinating, controlling and scheduling rapidly changing inputs, monitoring the complex response outputs of students, and providing for realistic interaction between the two are rapidly outstripping the capabilities of human instructors. Likewise, the requirements for rapid recording and analysis of complex, multivariate events is increasing, and it is upon this function that providing knowledge of results to the trainees and programing future instructional exercises is dependent. All of these facts point to the conclusion that there is a class of military training problems where the role of the instructor must be taken over to some degree by automatic equipment. Here, of course, we are dealing with quite a different type of automated training device from the relatively simple, inexpensive teaching machines used in presenting classroom instruction, but the concepts and rationale are the same. We are discussing an automated or self-instructional simulator. In such a simulator, the machine, in addition to its usual role of providing system simulation, takes on the functions of automatically recording and evaluating trainee performance and of adaptively programing subsequent events to maximize the trainee's approach to criterion performance. Computers, with their capacity for short term storage of huge amounts of information, rapid search and rapid computation are well suited to perform these functions which humans perform quite poorly. With machines performing these functions, high quality instructional personnel can be used entirely for tasks such as determining what aspects of human performance to record, formulating criteria of performance adequacy for various stages of training, and developing programs of problems for the simulator. These are things which the machine cannot do. Thus, we have both men and machines doing those things which they do best and, once again, improved training should be the result. Automated simulators as operational training tools are still somewhat in the future and considerable development work remains to be done, but the Eucrates device described in Section II has proved that the concept is definitely feasible and necessity should soon force the issue.

Use of Machine When No Human Instructor Is Available. In some situations automated training devices are desirable for the simple reason that no human instructional personnel are available. In such cases, if instruction is to be carried on at all, some type of self-instruction is required. There are a number of military situations where this is true. Some examples are remote or isolated early warning radar or missile-launch sites aboard naval vessels and, in the near future, aboard orbital or space vehicles. In all of these examples, of course, the type of training required is not initial training but maintenance of proficiency training. Individuals assigned to these military situations presumably would have been well trained in formal training courses prior to their assignment, but provision must be made for maintaining their proficiency on the job. This problem of maintaining proficiency will become more and more critical in the military as the expense and complexity of weapon systems increases, thereby reducing the opportunity for day-to-day practice of critical job skills. It seems obvious that missiles cannot be fired often for training purposes nor space vehicles launched to provide an opportunity for the crew to practice some particularly difficult portion of the mission.

Maintenance of proficiency training in military settings which are cut off from access to formal instructional facilities poses special problems, and it is in this area where automated training devices should prove very useful. Books and manuals have been used effectively for many years but they generally are of limited value in training for jobs which demand rapid decision making and/or perceptual-motor skills. In these areas, some type of automated training device would seem indicated. Types of devices which would prove useful pretty well cover the gamut of those discussed thus far and no further descriptions of devices will be made here. Rather, two brief examples of situations requiring automated training devices will be presented.

Remote, isolated early-warning radar sites involve a great deal of complex electronic equipment which must be maintained by the small complement of personnel stationed at the site. Since continuous operation of the radar screen is vital, prompt identification, isolation and repair of malfunctions is a necessity. To accomplish this, the ability of maintenance personnel to troubleshoot all types of possible malfunctions must be maintained at a high level. On-the-job experience cannot be relied upon to accomplish this, since the actual occurrence of malfunctions is fortuitous. What is needed are devices which can automatically present the maintenance man with a wide range of troubleshooting problems, assess his proficiency, and concentrate subsequent training in areas of weakness. Only in this way can the continued proficiency of the maintenance man in all aspects of his job be assured throughout his tour of duty.

Long duration missions, such as those involving interplanetary travel or extended orbital flight, could present some serious problems with respect to the maintenance of little used, but critical behaviors (Eckstrand and Rockway, 1960). For instance, according to present calculations, it would be several months from launch until a manually controlled soft landing on Mars could be effected. In the interim, there would be no opportunity for on-the-job practice. Thus, this extremely critical maneuver would have to be performed without even the benefit of warm-up. In the absence of firm research data to indicate that this particular skill is sufficiently resistant to forgetting, it would seem highly desirable to provide an on-board capability for maintenance of proficiency training. The same argument, of course, could be made for inflight maintenance tasks on long duration space missions.

MILITARY EFFORT NEEDED ....

As we have seen, there is no dearth of possible uses for automated training devices in military training. But listing possible applications for some new advance in the state-of-the-art is quite a different problem from assuring implementation. The history of military psychology, at least in the United States, is rife with examples of failure to achieve rapid and effective utilization of new techniques, methods, and devices. Although some of the blame for this may be attributed properly to the strength of tradition in the military, some must also be laid at the door of the military psychologist. We have perhaps not always been the best salesmen. It is entirely appropriate, therefore, that before concluding this paper we consider the problem of what needs to be done by military psychologists to justify the current enthusiasm for teaching machines and to insure their effective exploitation by the military.

To Assure Proper Use of Teaching Machines

Currently there are three areas in which military psychologists need to program their efforts to increase the probability that the potential of teaching machines will be recognized and used in military operations. These three areas are discussed briefly below.

Demonstrations of Effectiveness. Demonstrations of the effectiveness of automated trainers in realistic military training situations are needed to obtain required military support and to justify further interest in this field. Too often we have failed to realize the value of demonstration in military psychology and have neglected this important step. In our enthusiasm to put our ideas to work, we have often put them forward before testing the concept. This is not necessarily bad if the ideas have a great deal of logical validity, but the chances of getting our ideas accepted are reduced if their feasibility has not been demonstrated. In our eagerness to begin programmatic research on a concept or idea, we often have asked for support without giving hard-headed evidence of why such support is justified. We argue, with some validity, that research is required to identify major variables, their effects and their interactions before demonstrations can be accomplished. But, often valid demonstrations are possible long before completion of all of the detailed experimentation required to optimize conditions. In the teaching machine area we should strive to avoid committing either the error of pushing utilization without caution or of exercising too much caution by hiding our candle under a bushel of long-term research programs.

Such attempts to demonstrate effectiveness are not without hazard, of course. There is always the chance of failure due to a poor choice of conditions, and it would indeed be unfortunate if the real potential of automated training were beclouded by an early failure. As Bryan and Rigney (1959) have pointed out, there is also a danger that successful demonstrations will force a premature crystallization of teaching machine concepts and procedures. This would be quite unfortunate and certainly must be resisted. Nevertheless, the potential gains seem greater than the pitfalls, and efforts to demonstrate the effectiveness of teaching machines in military training situations certainly should be supported. Some attempts are currently being made to accomplish this and these efforts are a good start toward putting the program on a firm foundation.

Imaginative Planning For Use. Assuming successful demonstrations of effectiveness, the military psychologist then is faced with the task of assisting, and in many cases leading, in planning for the use of automated training devices both in existing training programs and in programs which are being developed to support new weapon systems. This will require imaginative and careful planning. No one or two successful demonstration studies will indicate where and when to push for the introduction of automated training devices. Yet, if history is any guide, the danger is that we will not use all that we know; rather than that we will go further than our knowledge permits. Therefore, it seems appropriate to recommend that military psychologists use all means at their disposal to assure that automated training technology is applied in all areas of military training where it appears to offer significant advantages over current practices. This will require salesmanship as well as science, but military psychologists must learn to mix these liberally to be effective.

Systematic Applied Research Program. We have a significant amount of information about teaching machines at the present time and can recommend their use with considerable confidence in a number of military situations. Nevertheless, if these devices are to be fully exploited, one of our primary needs is for an aggressive, systematic applied research program to further advance our knowledge in this area. If present trends continue, there seems little doubt that this need will be fulfilled without any special urging. Research in the area of teaching machines, after a number of rather lean years, is now increasing by leaps and bounds. Fig. 3-4-6, which is reproduced from Bryan and Rigney (1959), presents the trend over the past dozen years.

There seems little need, therefore, to make the usual plea for more research. Many competent investigators are busy identifying relevant problem areas and conducting programmatic research. We can expect with some confidence that much valuable information will be generated within the next few years.

It would be pleasant to end this discussion on such a reassuring note, but to do so would give the military psychologist a false

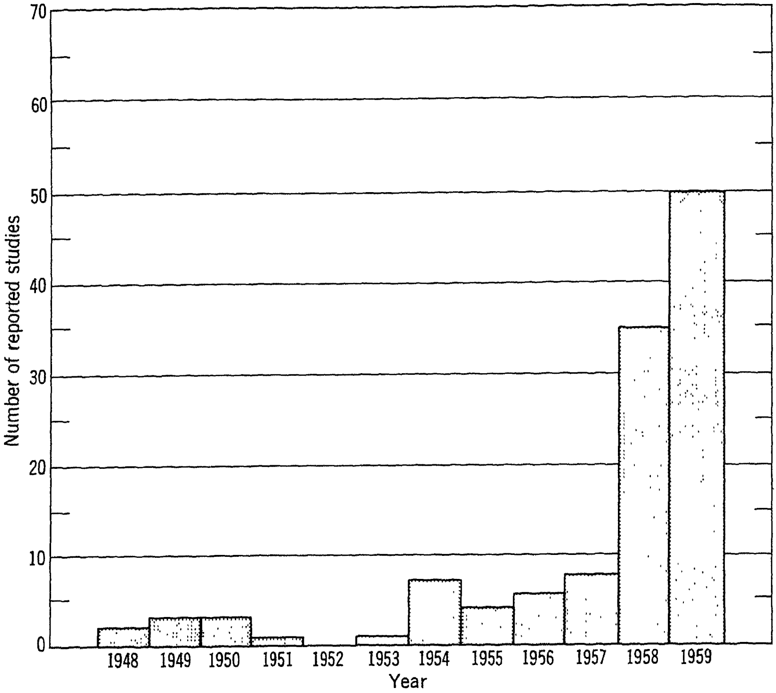

Fig. 3-4-6 Frequency per year of teaching-machine studies from 1948 to September 1959. There were six references prior to 1948.

sense of security. There are a number of problem areas which are closely related to the military uses of teaching machines which require study by the military psychologist before any large scale use of teaching machines can be recommended. Most of these problems are being neglected by current investigators. Some of them may not even qualify as research in the usual sense of the word, but their importance is not thereby decreased. Some of the more important of these problems are the following:

a. Motivational aspects of automated training. Trainee motivation has been discussed earlier as one of the challenging problems in military training to which automated training devices might make a contribution. Yet, little is known at present about the long-term motivational properties of these devices, and an answer to this question is basic to their large-scale use. Great teachers have long been known for their ability to motivate and inspire their students and there probably will be no such great teachers among the teaching machines. On the other hand, there probably will not be any really bad ones either. Teaching machines can be designed so as to present instructional materials in an efficient way. What we need now are some studies as to how they can be designed so that the student's response to them will be positive both initially and on a continuing basis.

b. Support requirements of automated training. The types of facilities, services, and personnel support required to operate conventional training programs have been well worked out through the years. One of the biggest dangers in the immediate, large-scale use of teaching machines is that users will expect that no changes in supporting facilities and services are necessary or, still worse, that these devices can be expected to function relatively autonomously in the training environment. Although we know that this is not true, we are not yet able to specify clearly and with confidence the nature and amount of support that will be required. High priority should be given to studies which will assess the impact of automated devices on current training concepts and programs.

c. Integration with other types of instruction. It is inconceivable that automated training techniques will ever completely replace other forms of instruction. Rather, they will serve as supplements, in some cases rather substantial supplements, to so-called conventional methods. Considerable research will have to be accomplished before we can specify the ultimate role of these devices in training, but much can and should be done at the present time to assure their efficient and proper integration into current and planned training programs.

d. Costing analysis. Machines cost money; sometimes substantial amounts of money. They also require maintenance; sometimes substantial amounts of maintenance. All this adds up to a definite price tag, including both direct and indirect costs, attaching to any automated training program. People cost money, also, even though their cost is not always as obvious as with machines. Any decisions to substitute machines for people in a system will have to be based not only upon the relative capabilities of the two to accomplish the functions assigned but also upon the comparative costs involved. This will be especially true in the area of training where the military is quite cost conscious. Therefore, military psychologists will do well in their studies, if they not only gather data on training effectiveness but also make provisions for a thorough cost analysis of the technique being studied. Such cost figures undoubtedly will be required before the military will make any large-scale use of automated training techniques.

e. Improved specification of training goals. A clear specification of the goals of the training is a requirement for developing any program of training or education; it is by no means unique to a program involving teaching machines. With teaching machines, however, this issue is brought into clear focus because materials must be prepared down to the finest detail, tried out, revised and standardized before training begins. With teaching machines there is no such thing as going to class unprepared and ''bluffing your way through.'' Nor is there much chance for hiding one's uncertainty about training objectives in wordy, highly generalized lectures. Rather, the exact material to be presented and mastered must be selected and programed in advance. This means that the teaching machine programer must come to grips with the goals of his training program early and without equivocation. The success with which this can be done is one factor which will determine both the effectiveness of teaching machines and their acceptance by training personnel. Therefore, a very important research requirement for the military psychologist is that of developing new and improved techniques for the detailed specification of training goals and standards before training begins, rather than by an after-the-fact analysis of the graduates of training programs. Such developments will have wide applicability to the field of training in general, but they are especially vital for the effective use of automated training in the military.

It is clear that there is no reason for the military psychologist with an interest in automated training to be idle in the next few years. There is much to be done, the time is ripe and the potential payoff is high. No one can say for sure at present what the future holds for teaching machines. Several highly ingenious and imaginative accounts of teaching machines' possibilities have been put forward, e.g., Ramo (1957, 1959). We certainly do not deny a bright future for these devices, but we believe that any such bright future is best assured by a well conceived, step-by-step building of the present. About the only prediction we can make with confidence is that the next few years in this field will be active ones.

There is a great deal of current activity and study in the area of teaching machines; these devices appear to have considerable potential for the field of military training, but there still is much work to be done before this potential can be fully realized. Actually, today the practical use of self-instructional devices and materials is merely in its infancy, but perhaps no single idea in military psychology since the selection test has created such interest and has had such far reaching implications for improving military operations. This is truly not only a great opportunity for military psychology but also a great challenge and a great responsibility. There is the opportunity to develop a tool which will bring considerable attention and great credit to our profession; there is the challenge of a psychological problem with depth and meaning; there is the responsibility to perform a significant service for the military organizations of which we are a part and from which we derive our support. It will be important for military psychology to meet this opportunity, challenge and responsibility with enthusiasm and maturity.

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SECTION 4. Computer-Based Teaching Systems

Teaching machines usually are designed to produce results that approximate as closely as possible the results of studying, not with the average teacher in a classroom situation, but with an exceptionally skilled, highly trained, human tutor. In some ways the designers of machines and programs have been quite successful, but there are many problems still to be solved. One of these problems concerns the ability of a tutor to vary the kind of material to be worked on and the techniques to be used according to the progress the student is making at various stages in the learning situation. The fact that students using programed instruction do make specific responses to a program makes it possible to construct a teaching system that can use and base decisions on this data. Because a great many decisions are involved, the electronic computer comes easily to mind as an appropriate instrument with which to implement such a teaching system.

The possibility of actually constructing machines to meet the specifications described above seems to many to be as incredible as science fiction, yet actual attempts are being made in this direction. The first article in this section, for example, describes some of the theoretical bases on which the Systems Development Corporation has constructed a computer-based teaching system. A much less complex means of letting the students' responses control the organization of the program is described by Norman Crowder in the second article in this section. This article describes systems that, although student-controlled, are much more economical than the usual high-speed computer-based teaching system.

In contrast to these, the third article in this section is a theoretical paper. It describes a model on which teaching-machine development and research can be based. Although the reader might have difficulty with the theoretical bases for the model, or may not understand its derivation, the discussions in the non-mathematical parts of the text are well worth the attention of anyone engaged in research and development of automated teaching systems.

Computer-Based Instructional Systems

By JOHN E. COULSON, DON D. BUSHNELL, and
JOHN E. COGSWELL
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At first thought, it might seem difficult to justify the use of a computer, with its associated cost and complexity, in an automated teaching system. In this connection, certain statements should be made at the start. These are as follows:

a. The finest automated teaching system can be no better than the instructional materials, or "items," used in the lessons. It is impossible to over-estimate the importance of well written items that are carefully prepared and directed toward clearly defined educational or training goals.

b. Given a set of well prepared instructional materials, effective automated instruction can be provided under many conditions with extremely simple devices or even with specially organized textbooks.

c. For some training situations, a computer-based system would be unnecessary, uneconomical, and undesirable.

THE ADVANTAGES

On the positive side of the ledger, a computer-controlled instructional system offers a number of valuable capabilities that cannot be matched by simpler devices or systems. Among these are the following:

a. The operational characteristics of the modern digital computer are not fixed by the design of the electro-mechanical components. Rather, they are largely under the control of the "program"** that has been read into its memory. Thus, the computer-controlled instructional system provides great versatility of operation without the need for costly hardware modifications. This versatility is of particular value during the early developmental stages in the introduction of an automated instructional system. By appropriate program changes, the computer can be made to function in many different modes that can be compared for relative training effectiveness in the particular instructional context in which the system is to be applied. In this way, it is possible to simulate and evaluate proposed, as well as existing, instructional configurations.

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*System Development Corp. (SDC) is a nonprofit corporation concerned with national defense and public welfare. It does not manufacture equipment for sale nor endorse individual manufacturers or their products.

**In this article, the term "program" refers to a set of computer instructions, not to the instructional materials seen by the student.

b. With a computer-controlled instructional system, each student or trainee can be given the sequence of instructional materials best suited to his needs. Highly refined techniques for the evaluation of student capabilities and performance can be built into the control program that determines the sequence of materials and mode of instruction for each student. In this way, the student with more experience or higher aptitude can be taken through the entire course with a minimum of delay, whereas the slower, or less experienced, student can receive as much supplementary training as is necessary to bring him to the required level of performance.

c. A general-purpose digital computer has capabilities that permit its use, not only for instruction, but for numerous other tasks that might be of importance to a military, educational, or industrial organization. Its extensive memory can be used for storage of student attendance and performance records as well as information about each individual's aptitude, family background, previous training, or any other pertinent data.

d. The computer's ability to perform rapid calculations permits the analysis of data for summary or predictive purposes, and its logical circuitry can be used to generate class-assignment lists and training schedules.

e. By appropriate time-sharing techniques, a computer can be cycled through a number of tasks in such a way that it appears to be performing all these tasks simultaneously. In other situations, the computer might be used during certain hours of the day for instruction and during other hours for data storage and analysis.

Computer-based teaching machines appear to have particular advantages for the types of training problems encountered in the military and in industry. Trainees in these areas vary markedly, not only in basic ability and personality, but in their educational and training experience as well.

Research with the teaching system using a Bendix G-15 computer indicates that, with appropriate individualization of instruction, students of relatively low ability and experience can be brought to the same level of performance expected of more intelligent and experienced students (Coulson, et al., 1961). Thus, by adjusting the training to the individual differences of the trainees, the potential supply of adequately trained manpower can be increased.

The time required for training is of critical importance in the military and in industry, especially where crash programs in the interest of national defense call for rapid training and retraining. Research has shown that instruction time can be reduced significantly by the branching method as compared with the linear method. (Coulson and Silberman, 1960).

Training requirements in the military and in industry also call for diverse types of training. For example, some skills demand proficiency in perceptual motor performance; other jobs require both conceptual and motor learning (as with electronic trouble shooting); and depend, primarily, on verbal learning. The computer-based teaching system allows wide versatility in the design of training procedures. This versatility should reduce the requirement for procuring many different types of equipment to fill various training needs.

SOME POTENTIALS

The capability of military and industrial organizations to fulfill their objectives in the time limits set by contractual commitments and project deadlines is directly related to the efficiency of the functions and interactions among management, personnel, and training units. Computer-based instructional systems have decided potential for strengthening the power of these functions and interactions.

The computer-based system could be used, not only for analyzing the responses of trainees and controlling the presentation of stimulus materials, but also for collecting and storing large amounts of information about the learning behavior of the trainees. This information could be used advantageously by both management and personnel.

Timely information on the individual progress of trainees in training could be transmitted and displayed to management. In this way, management's ability to predict more accurately the availability of manpower for assignment would be increased.

The detailed descriptive data of the trainees' learning behavior also could be used by personnel. Such information could be related to vocational-aptitude and mental-ability test scores to allow more accurate prediction of the individual difference variables associated with rapid learning. Thus, the efficiency of selection of men for training could be increased.

Recent developments and trends in both computer technology and information processing have additional implications for the application of computer-based instructional systems to the military and to industry. In the future, a computer-based library might be connected to a national repository of technical and scientific information. Trainees at consoles in this library could call up information on the current state of knowledge in any area. In a given study area, students or trainees in individual cubicles might instruct themselves with the aid of a machine tutor. Each tutor could be linked, through the instructional computer, to a national information-retrieval system that would process written data into courses of study, develop diagnostic questions, and search for answers to questions asked by students.

ITS FEASIBILITY

Considering the cost of computers, how feasible is a computer-based instructional system? Initially, the cost might be prohibitive, but, in industrial and military organizations where computers are now being used for various data-processing and control functions, the cost might be reduced by time-sharing existing equipment. Also, the research and development of small special-purpose computers in the future might reduce the cost substantially.

In the final analysis, cost must be considered in relation to system objectives. It seems unlikely that computer-based instructional systems will make instruction less expensive, but they should certainly make it much more effective.

TWO COMPUTER-BASED SYSTEMS

The following paragraphs of this article describe work being done by System Development Corporation (SDC) on computer-based instructional systems. These systems, designed largely for research and development purposes, are not presumed to be ultimate or ideal configurations. A consideration of their functional characteristics, however, might give some indication of the potentials of the modern computer for training and educational systems of the future.

An Experimental Facility for Individual Instruction

Early in 1960, SDC completed work on a computer-based facility designed for research in the field of automated instruction. This facility (see Fig. 4-1-1), which teaches one student at a time, consists of three major units: a Bendix G-15 computer, a random-access slide projector, and an electric typewriter.

Bendix G-15 Computer. This computer serves as the central control unit for the system. It contains the master control program that governs the operation of the entire system. The computer determines, at all times during a training session, what materials are to be presented to the student. It analyzes student responses to the instructional material and compares these responses with stored data.

Rolls of paper tape, each of which can hold the necessary information for a different instructional lesson, are contained in

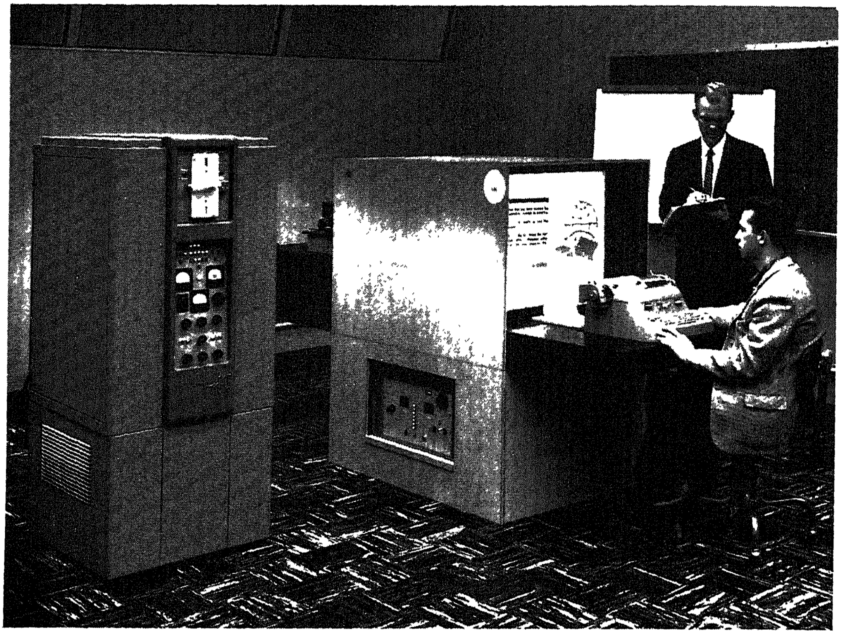

Fig. 4-1-1

easily interchangeable magazines. A bell mounted in the computer frame can be rung by the computer for programed auditory signals.

Random-Access Slide Projector. Developed by the engineering staff at SDC, this projector holds up to six hundred 35 mm slides in 15 magazines of 40 slides each. It receives instructions from the G-15 for selecting and projecting instructional slides in the sequence indicated by the computer.

Electric Typewriter. Two primary functions are served by the typewriter, which is linked to the Bendix computer. First, the student uses the keyboard to insert his answers to the instructional materials, which are normally in multiple-choice form. Second, the computer program takes control of the typewriter to print messages telling the student how successfully he has answered the questions.

Functional Characteristics of the System. The student begins with a basic series of items, each of which he attempts to answer in multiple-choice fashion by pressing a key on the typewriter keyboard. He receives appropriate knowledge of results after each attempt. Every item presented to him is registered within the computer's control unit as having relevance to one or more specific topics to be taught. The computer keeps a record of the student's performance on each item and a cumulative record of his performance on each of the topics covered by the items. These performance measures can include the student's responses times as well as his error count.

If the student's performance falls below a certain level for a particular topic, he is "branched" to a special set of items that provides remedial work on that topic. He may be taken through the entire remedial routine or only a part of it. When the student returns to the basic series from the remedial routine he continues until he has finished this series or until his performance once more falls below certain programed limits. In this event, he is again "branched," temporarily, from the basic series.

In certain cases, a single missed item on a particular topic might be sufficient to take the student to a remedial routine. The system not only recognizes that an item has been answered incorrectly but, also, considers the specific incorrect alternative chosen. Certain answers might be indicative of a serious misunderstanding by the student, in which case the system would "branch" immediately to a remedial sequence.

If a student does very poorly in his training and requires excessive remedial work (according to programed criteria), the system can take him completely out of the original series and "branch" him into an alternate basic series. This alternate series would represent, not simply a remedial routine, but a major change in the training approach. The original series might, for instance, use the procedure of first giving general rules and then presenting examples to illustrate the rules; the alternative series might reverse the order by gradually building up to a general rule through a progression of illustrative examples.

In the event that a student's performance on some topics of a basic series is sufficiently high, the teaching machine can skip certain items of these topics, thereby allowing the brighter student to progress rapidly to more advanced topics.

At various points during the training session, the system might require the student to indicate his degree of confidence concerning his own learning progress. If he expresses a feeling of confusion or lack of understanding, he might be taken to a remedial branch even though his actual performance is above the normal-criterion level for such a branch. An expression of great self-confidence, on the other hand, might cause the student to be returned more rapidly from a remedial routine to the main sequence.

A Facility for Individual or Group Instruction

The previously described computer-based system instructs only one student at a time. A newer facility (see Fig. 4-1-2), des-

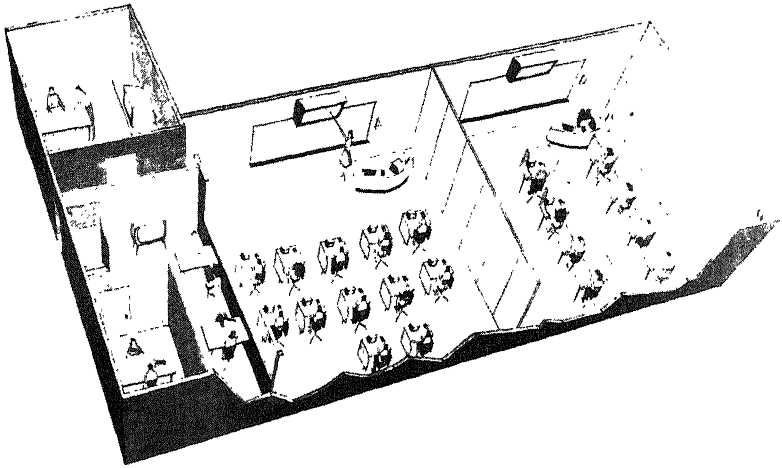

Fig. 4-1-2

ignated CLASS (for computer-based laboratory for automated school systems), makes the same individualized form of autoinstruction available to 20 trainees studying simultaneously. With CLASS, self-instructional programs can be combined with conventional instruction or with large-group automated instruction that uses some of the properties identified with individual teaching machines (e.g., immediate feedback, controlled sequencing, and prior programing). Through central mediation by a Philco 2000 computer, CLASS provides automatic data processing for many of the functions normally associated with educational systems, (e.g., scheduling, testing data analysis, and accounting control).

This computer-based laboratory is part of the larger Systems Simulation Research Laboratory at SDC. It was designed as a general purpose facility in which existing or proposed educational systems can be investigated (Bushnell and Cogswell, 1961). The physical plant consists of an administrative area, a counseling and observation deck, a large automated classroom area, and a central projection room (not shown in the illustration). The classroom area is shown divided into two rooms by a sound-attenuating folding wall. This wall makes it feasible for instruction to be given simultaneously in two different subject areas and in two modes of automated instruction, i.e., the group and individual mode. When the wall is folded away, a large group area is available.

For training directors or administrators, a 900-line-per-minute, high-speed printer under computer control makes available information on the state of the academic progress of each student as well as other data useful for management purposes. Less urgent reports—necessary for scheduling and curriculum planning and for budgeting and accounting—can be retrieved when the computer is not selecting and analyzing instructional programs.

The observation area includes a small counseling room in which is a teletype unit that is connected to the computer for recording and reporting diagnostic data and for calling up information needed by the counselor or interviewer. All of this data is stored on magnetic tape along with the student's educational record (continually updated by his daily performance), previous school record, aptitude measures, and other relevant information.

In the observation area, observers are able to monitor visually the behavior of students and teachers in the classroom and the counseling room through a one-way-vision glass window. In the event that the folding wall is used, as shown in the illustration, to divide the large area into two classrooms, a closed-circuit TV camera and monitoring unit permits observation of the remote classroom. Microphones placed in the classroom also permit observers to monitor aurally the behavior of students and teachers.

Individual Instruction with CLASS. Individualized automated instruction is made possible through the electronic components on each student's desk. Each student has the film viewer and response device shown in Figs. 4-1-3 and 4-1-4. The response device is connected to the computer through a buffer system.

The trainee begins his lesson with a sequence of educational items or frames presented by his film viewer. Some of the items are multiple-choice questions testing the student's knowledge of the subject material. The student responds to the question by pressing one of five translucent keys on his response device, which key then lights up. After the student is certain of his selection, he presses the "Enter" bar, which transmits his choice to computer. The computer analyzes the response and provides knowledge of the results by turning on a light to the left of the response key that corresponds to the correct multiple-choice option. A red or a green light at the top of the response device also can be turned on by the computer to indicate the correctness of the choice.

A cumulative record of the student's performance on each of the topics is kept by the computer. These performance measures include the student's response time, error count, and a record of

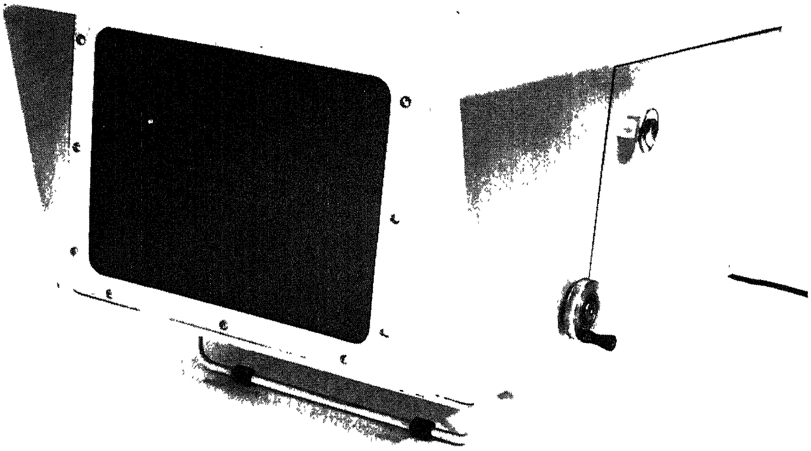

Fig. 4-1-3

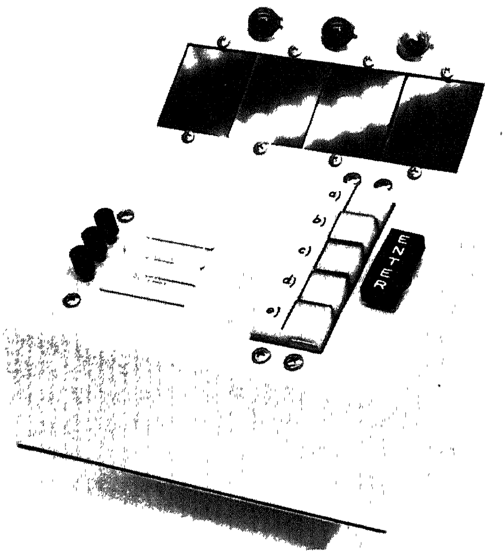

Fig. 4-1-4

specific alternate choices. As with the previously described system, if a student's performance falls below a certain level for a particular topic, the student is "branched" or detoured to a special set of remedial items on that topic. The brighter student might not be remedially branched at all.

When the student has read a frame of material, responded to the diagnostic question, and received knowledge of whether his response was right or wrong, he is ready to continue. He now presses the "Enter" bar, which turns off the lights on his response device, and the number of the next instructional frame appears in the read-out panel. The student manually winds a film strip to that frame and repeats the cycle.

At any stage during the training period, the student is allowed to review at his own option. If he presses one of the three buttons on the side of his response device, he will be instructed to turn to an item listing several areas for review that are related to the concept in which he has just been working. The appropriate review items are then read.

If the student needs excessive remedial work, an auxiliary program can be read in from magnetic tape. The student now can proceed on a new series of educational items that could range from a different training approach to a change in media.

The manually-operated film viewer that presents the instructional items holds 35 mm film strip with a capacity for 2,000 frames. The illumination of the screen is sufficient for reading under daytime ambient-light conditions. Each student's desk is equipped with movable independent-study panels that can be easily brought into place and then lowered to become a part of the desk.

The Teacher's Components. The teacher has four sources of information available with which to monitor student learning behavior. These are a teacher's display console, a film viewer for monitoring the educational program, a response device similar to the student's unit, and a digital display monitor. As can be seen in Fig. 4-1-5, the teacher's display console has ten "switchlight" buttons, each button corresponding to a single student's station. Five other buttons permit different kinds of actions to be taken by the teacher. An "Enter" bar allows the teacher to change her action before inserting it into the computer.

When an instructor initiates a period of automated individual instruction, he inserts the student's assignment from punched cards and presses one of the "Action" buttons. This causes a student-history tape to be brought into the computer memory. The tape indicates where the student is in his lessons, his IQ, and his previous grade record. Another magnetic tape (the subject-matter tape) then is read into the computer to present the day's lessons to each student.

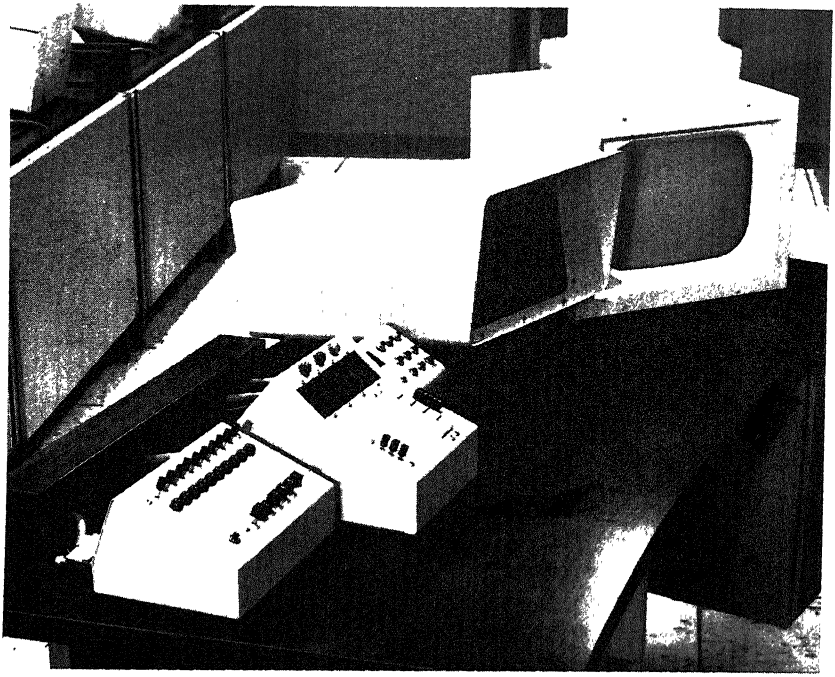

Fig. 4-1-5

As the students enter their responses to the instructional items, the computer monitors individual student response behavior. When a student is experiencing difficulty, i.e., he makes a prespecified number of errors, a significant error, or has an excessive response latency, a button lights up on the teacher's console. (This same light can be energized by the student who wishes assistance.) The teacher responds by pressing the button (which turns out the light) and by pressing an ‘‘action’’ button on his console.

In response to this action, the computer furnishes a display of the student's performance through the digital display monitor. The student's performance read-out will contain the following information:

a. The student's number.

b. The reason for the alarm.

c. The name of the concept or topic on which student is working.

d. The number of errors on the present concept and the total number of items on this concept to which the student has responded.

e. The number of errors for the lesson and the total number of items to which the student has responded.

A second "action" button puts the teacher's response device in parallel with the response device of any student. The teacher then can monitor the student by observing the student's responses on the teacher's response device and by reading those same items on the teacher's film viewer with which the student is apparently encountering some difficulty. Other "action" buttons on the teacher's console allow him to start and stop lessons, reassign students to new stations, and call-up other analyses of student learning behavior.

Group Instruction with CLASS. For group instruction, the TV screen and speaker serve as a common group output for different kinds of audio-visual presentations. An audio-visual system of remotely controlled slide and film projectors enables the teacher, from the front of the classroom, to call up films or other displays; to stop the frame of the display, whenever it is appropriate, for group discussion; to repeat short film strips or sequences of film when needed; and to teach the group by an automated program that is sequenced and selected by the computer.

During the actual class period, the instructor can schedule a film or series of slides for a specific time. When it is appropriate, the teacher switches on the TV screen and turns to the channel on which appears the first frame of the film or slide to be used. If, during a lecture, the teacher wishes to run a film or slide or stop on a frame, he can press the button appropriate to the action. With a call to the projectionist in the audio-visual center, he can arrange for additional films or magazines of slides.

If the teacher wishes to intersperse his lecture with diagnostic questions to which the student should respond with his response device, the teacher can receive an immediate read-out on his digital display of certain group, subgroup, or individual student measures that indicate the degree of student understanding to help him to redirect his instruction. The teacher also can signal the correct response on the student's response devices by activating the device at his desk.

An automated group-instruction session, without the teacher, can be effected by computer control of the random-access projector now being used in the experimental facility previously described. Group knowledge of results can be acquired simply by giving the correct answer on a slide following each item that has a diagnostic question associated with it. Individual feedback is supplied on the student response device.

Further Development. Although the present configuration of CLASS is based on experience gained with the previously described computer-based teaching machine and on SDC's general experience in the systems training and data-processing fields, it is not considered an ideal or fixed design. The results of research with the facility will undoubtedly lead to modifications and improvements. Moreover, developments in hardware and computer technology can be expected to cause continual re-evaluation of the design of CLASS.

A prototype unit, manufactured by the Kalart Company, simultaneously presents audio material over a headset and visual material on film strip. The sound record is photographically printed on the film. Eighteen seconds of sound recording can be stored on each frame. With the Kalart unit, a single student can be machine-tutored by a teaching machine that has both random-access slide and audio display. This could be an important capability in comparing different sense modalities with students of different aptitudes for different subjects.

A Simulation Laboratory. The use of a simulation facility like CLASS can aid substantially in the design and implementation of advanced instructional systems. By studying alternative methods and procedures in a laboratory where the environment is realistically simulated, many potential problems can be uncovered and effective operational procedures can be developed and tested. In addition to providing a simulation facility for research and development of instructional systems, a laboratory like CLASS permits training through simulation.

The use of computer-based systems for such a purpose is not without precedent in the military and industrial environment. An IBM 650 has been used by the American Management Association for training top management through simulation procedures. Trainees make judgments concerning competitive business situations and enter their decisions into the computer. The computer processes the information, interrogates the trainee further, and supplies him with knowledge of results indicating probable consequences of his actions (Craft and Seward, 1959). Within the military, the SAGE system training program provides simulation of inputs to the SAGE air-defense system through a digital computer. During an exercise each crewman in the system receives information that reflects the consequences of his own actions as well as the actions of other members of the system (Miller, 1960).

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Simple Ways to Use the Student Response for Program Control

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When we consider the application of computing techniques to teaching machines, we come at once to some very fundamental issues in the field of automated instruction. As a beginning, we should distinguish clearly the structural differences between linear, or what I will call *nonresponsive* programing techniques, and branching, or what I will call *responsive* programing techniques. We must also examine the theoretical basis for these differences in structure.

It is characteristic of all teaching-machine methods that they require, or at least provide an opportunity for, an active response on the part of the student at frequent intervals throughout the program of instruction. There have been two schools of thought as to the primary reason for eliciting the student's response. Indeed, the two schools represent historically independent developments and spring from differing theoretical backgrounds.

One school of thought, having its roots in classical experimental psychology, views the student's response as an integral part of the learning process and, therefore, as a legitimate end in itself. The adherents of this school are satisfied, in general, to make no further direct use of the student's response other than for its assumed effect on the student. This school has always, of course, emphasized the use of the records of student responses in the development and revision of a program, but not in the administration of it. Because the student's response is not used to control the program, the resulting programs are of the linear, or nonresponsive, type.

The other school, having its roots in differential psychology, is primarily interested in utilizing the student's responses to control the course of the programed material presented to that particular student. Adherents of this second school generally have preferred to beg the question of exactly how the learning was to take place so as to focus attention on being able to determine, from step to step in the program, whether learning *had* taken place. Given this information in usable form, it is then possible to arrange that the program be automatically modified until the desired result, for that student at that time, is attained. This second school, therefore, is interested in the student's response as the primary datum required to operate a branching, or responsive, program.

I would not argue that we should ignore the effect of the student's response on the student any more than we should ignore its possible use in automatically controlling and modifying the instructional program. Nevertheless, it should be pointed out that, when we consider the use of computing apparatus to modify the instructional program for an individual student, we are interested primarily in this second use of the student's response and, by definition, are contemplating branching, or responsive, programs. To make full use of whatever computing capability we employ, we need to realize that a branching program has definitely different structural characteristics than a linear program and, also, has different capabilities.

I hope I have not been tedious in drawing attention to this fairly obvious point—that computer control implies branching programs. One reason I feel this point deserves some emphasis is that it was not very long ago that I heard a prominent educational psychologist refer to those of us who were interested in branching programs as a "vociferious minority" and suggest that our numbers should not be judged directly by the amount of noise we made. I take it, by the current interest in means of controlling branching programs, that the ranks are swelled somewhat, although perhaps with quieter members. This, however, is beside the point.

There are two major aspects of branching, or responsive, programing that I wish to call attention to before discussing my major topic, which is the choice of techniques within the general area of responsive programing. The first point I want to make is that branching, or responsive, programs will, I predict, utilize multiple choice rather than completion questions, and for a purely practical reason. It is simple, easy, and convenient to let the teaching machine, whatever form it takes, know which of several alternatives a student has chosen and to cause it to take appropriate action on the basis of this choice. It is virtually impossible, in the present state of the art, to let a teaching machine "know" what answer a student has given when the student has written out or "constructed" his answer. This purely practical consideration was, of course, my reason for originally preferring the multiple-choice-response mode, and, if I understand the research of the last year correctly, I believe that the theoretical reasons for preferring the constructed-response mode have been swept away by the experimental evidence. To use, I believe, Evan's phrase, multiple-choice responses are now allowed to sit at the same lunch counters as constructed responses. Reversing the usual geographic pattern, this form of integration seems now to have spread as far north as Boston and environs.

There are some curious cases where there is no difference between the multiple-choice and the constructed-response format. These are those cases in which the universe of sensible responses is strictly limited to a finite number. Thus, there are only 26 possible alternatives for the next letter in a spelling problem, ten alternatives for the next digit in a problem in decimal arithmetic, and only two in problems in binary arithmetic. In these cases, the distinction between the multiple-choice and constructed-response format disappears.

The second major point I want to make about branching, or responsive, programs is that when we focus attention on the student's response as the primary datum needed to operate our branching program, rather than as a part of the learning process as such, we become aware that the questions in our program may serve a variety of different functions and that these different functions require different types of questions. A routine question on a routine step in the program should serve to do the following:

a. Determine whether the student has learned the material just presented.

b. Select appropriate corrective material if the student has not learned.

c. Provide desirable practice with the concept involved.

d. Serve to keep the student actively working at the material.

e. Presumably, if the student gets the question right, serve a desirable motivational purpose.

It is quite possible, however, that we will, in writing branching programs, write questions that serve none of these purposes. We may want a very "stiff" question, or a short series of "stiff" questions, to determine whether a student should skip a whole block of material. Such a question, as presented to the student, might not accomplish any of the purposes served by the question used in a routine program step. Again, this point might seem obvious, but I merely wish to point out that there is no reason to view each program step and the associated question as having the same function and, therefore, the same structural and statistical properties. For example, I think it desirable that, on a routine program step (if there is such a thing), no more than 15% of the students should select a wrong answer. But a major program branch might have a question that would be failed by 90% of the students.

It might be somewhat less obvious that the alternatives provided in a single multiple-choice question also might serve different purposes and have different consequences. One alternative might be provided to catch a particular procedural error and lead to a single corrective presentation; a second might be such that it appropriately leads to a correctional subsequence; a third alternative might catch an error of interpretation on a point made previously and lead the student back to that point in the program to work his way up again. All of these kinds of contingencies are fairly easy to provide for.

After this long preamble about the rationale of responsive programs, I would like to turn now to my major topic, which is the several means of accomplishing branching programing. We can distinguish two basic types of branching programs. There is the type of branching program in which there is a one-to-one correspondence between the student's answer choice and the next material he sees. Thus, the student's answer choice might lead him to turn to a particular page in a "scrambled" book or to press a particular button on a machine, at which point a particular, predetermined presentation appears on the viewing screen of the machine. This type of responsive programing requires no intermediate computation between the student's answer choice and the decision as to what material he will see next. I call this type of responsive programing *intrinsic programing*. When, in addition to the student's response alone, we use other data and perform further computation to select the next material the student should see, we have what I would call *extrinsic programing*.

I would like to inject an historical note at this point. When I first began to work in this field in 1955, I assumed that any type of auto-instructional program could usefully be classified according to the technique used to provide the branching and, therefore, coined the terms "intrinsic" and "extrinsic" programing. It did not occur to me that anyone would seriously propose an auto-instructional program that did not provide any means of automatically varying the program to accommodate the needs of different students.

The intrinsic programing technique has the obvious advantage that no complex computing equipment is required for its implementation. The simplest device utilizing intrinsically programed material is the "scrambled" book, and, with relatively simple devices (simple when compared to the complex computers now being proposed), quite complex kinds of branching programs can be used.

In principle, it is true that, with the simplest form of intrinsically programed material (the scrambled book), any branching program that depends only on the history of the student's choices can be accommodated, as can be seen in Fig. 4-2-1. A three-step program is shown, with two choices at each step. Each of the students arriving at a different point (A through H) on the third step has a different history, and yet in no step have we considered any data beyond the student's present location and his immediate choice.

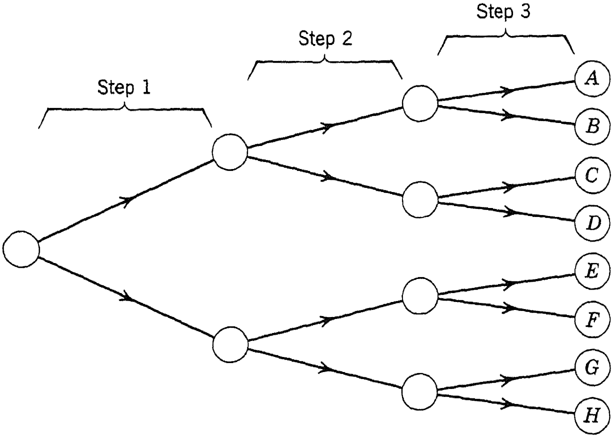


Fig. 4-2-1

It would appear from Fig. 4-2-1 that the number of pages or locations to be provided becomes very large if the program is more than a few steps long. In practice, however, this is not the case because most of the student's history probably is irrelevant for the choice of what to do with him at any given point in the program. If we carry this idea to its extreme, we get the kind of pattern shown in Fig. 4-2-2, which is the simplest kind of branching pattern. In this pattern, branches representing errors are "cut off," and the student, after correction, is returned to the point at which he branched, as implied by the double arrows on the branches. With this type of sequence, the number of pages becomes manageable.

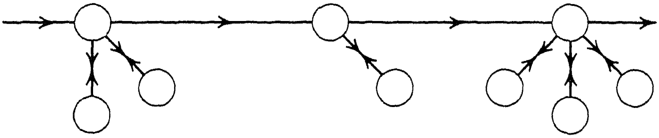


Fig. 4-2-2

A more complex, but still practically useful, sequence is shown in Fig. 4-2-3. The chief characteristics of the sequence shown in Fig. 4-2-3 is that a student making any error in Step A is placed in a subsequence that will lead him eventually to the next step, but only if he passes the criterion question at A', which covers essentially the same material as the question A. Again, notice that, in this sequence, the only data required to determine where the student should go next is his present location and his immedi-

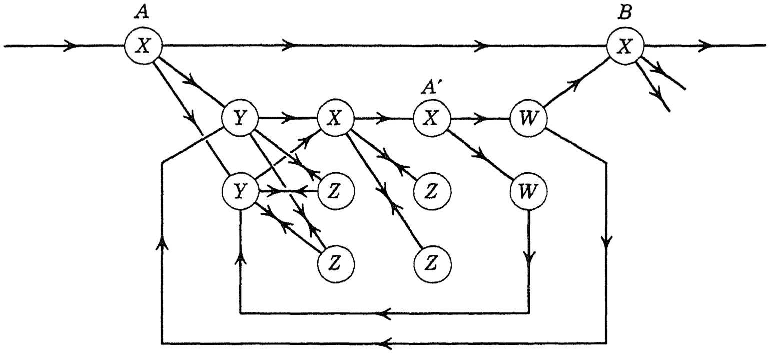


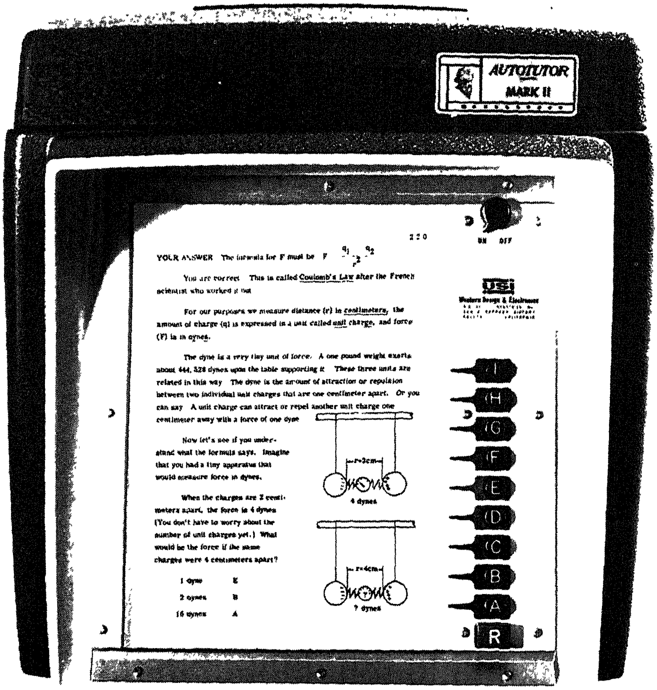
Fig. 4-2-3

ate choice. The branching program therefore, can, be accommodated in such a simple device as a scrambled book.

A somewhat more complex device, the Auto Tutor Mark II shown in Fig. 4-2-4, handles similar material, but adds some new dimensions of control. The actual material is handled on a roll of 35 mm microfilm. The student sees this material projected on a viewing screen and has ten response buttons that he uses to answer the questions. The actual effect of each of the ten buttons is as follows:

Button A advances film 1 step.
Button B advances film 3 steps.
Button C advances film 5 steps.
Button D advances film 7 steps.
Button E advances film 9 steps.
Button F advances film 11 steps.
Button G advances film 13 steps.
Button H advances film 15 steps.
Button I rewinds film 19 steps.
Button R cancels previous excursion.

Buttons A through H are the ones normally used by the student to answer multiple-choice questions. Each button advances the film the number of steps shown. If the student has chosen the correct answer to a question, the film frame on which he ends up will contain new information and a new question. When the student again presses one of the buttons to answer the new question, the film will now advance from the new location. If the student has chosen an incorrect answer, the material he sees will, in the simplest case, present correctional material and then direct him to press the R or return button. This action will reverse the excursion the machine has taken immediately previously and put the



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YOUR ANSWER The formula for F must be $F = \frac{q_1 q_2}{r^2}$

You are correct. This is called Coulomb's Law after the French scientist who worked it out.

For our purposes we measure distance (r) in centimeters, the amount of charge (q) is expressed in a unit called unit charge, and force (F) is in dynes.

The dyne is a very tiny unit of force. A one pound weight exerts about 444,328 dynes upon the table supporting it. These three units are related in this way. The dyne is the amount of attraction or repulsion between two individual unit charges that are one centimeter apart. Or you can say: A unit charge can attract or repel another unit charge one centimeter away with a force of one dyne.

Now let's see if you understand what the formula says. Imagine that you had a tiny apparatus that would measure force in dynes.

When the charges are 2 centimeters apart, the force is 4 dynes. (You don't have to worry about the number of unit charges yet.) What would be the force if the same charges were 4 centimeters apart?

1 dyne	E
2 dynes	B
16 dynes	A

Fig. 4-2-4

student back on the original question frame to have another try at the question.

This is the sequence of events, somewhat more conveniently arranged, that would occur if the student were using a scrambled book. Having the material inside a machine under mechanical control, however, enables us to add some very interesting new control features to the material. These controls are brought about by a code on each film frame that determines which buttons on the machine will be allowed to operate when the student is viewing the frame. There are four codes on the Mark II AutoTutor with the following functions:

a. Code X—all buttons work. This is the code used routinely on a right-answer frame. The student has just chosen the correct answer to the previous question. We are satisfied with his performance and have no reason to restrict the student's activity, nor does the student have any reason to do anything but what we want him to do, which is to choose an answer to the new question. If the student wants to review the previous right-answer frame, he can do so by pressing button R, which we allow to work in this case.

b. Code Z—only the button R works. All other buttons do not work. This is the code normally used on a simple wrong-answer frame. The student on such a frame has made an error, and we want him to read the correctional material and then to return to the question page. We arrange the situation so that only button R works in this case.

c. Code Y—only buttons A through H work. This code is used on a wrong-answer frame that introduces a correctional subsequence. The student has made an error, and we want him to work forward through a correctional subsequence. In particular, we do not want him to return to the question to try another answer. Therefore, we do not allow the button R to work from this frame.

d. Code W—only the I button works. The I button on the Mark II is the only button that runs the film backward. It, with the W code, is used to run the student back in the program, to review material previously covered, or, in a sequence of backward excursions, to bring the student back to the beginning of a complete section of the program.

With the use of these film codes, which appear on each frame of instructional material and are read by two photo-cells in the machine, it is possible to achieve great flexibility and, at the same time, exercise complete control over the options available to the student. It is literally impossible for the student to advance from frame 1 to, say, frame 400 of a program until he achieves the criterion performances we have required on the way.

I suppose it is a nice point whether the Mark II AutoTutor, with the film codes described, uses intrinsic or extrinsic programing. Whatever conclusion we might come to on this question of definition, it is nonetheless true that we use only data derived from the student's present position, the film frame he is presently viewing, and his immediate choice to determine what will happen to him next. My point in presenting this information in this much detail is to give some idea of the complexity of programing that can be accommodated without involving the more complex types of computing apparatus.

I would like to make one final point bearing on this matter of complex control of teaching machines. To my mind, it is the logic of the subject matter itself that always must be allowed first consideration in designing a program. No amount of computing capability can substitute for clear, well written programed material. This is unfortunate because it is easier to draw logic diagrams for computer programs than it is to write effective program material. Nonetheless, it is the material that will ultimately determine the success of the program. I believe that the field of programed instruction is now beginning to free itself of the restrictions resulting from adherence to a grossly over-simplified learning paradigm; I would hate to see it immediately succumb to a second type of restriction imposed by the possibility of using very complex formal control at the expense of paying close attention to the material to be taught.

* * *

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The Dynamics of an Automated Teaching System

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AUTHOR'S NOTE: Since we wrote this article in May, 1960, several teaching devices using digital computers have been developed. Some have merely used the computer to make a selection of the items to be presented to the student based on the student's responses to previous items and a preconceived, fixed set of branching rules. Others have used the computer to gather and process data on student performance for periodic review by the experimenter or teacher.

Both of these functions probably can be accomplished in a far less expensive fashion than by using an "on-line" computer in the teaching system. The promising future for computer application to teaching systems lies in the computer's capability of modifying the logic decisions governing the presentation of material to the student while he is learning. If the logic decisions are "canned" in fixed computer instructions (program), the speed capability of the device is not being used at its full potential.

Computers are being used to regulate the presentation of items and to record and analyze student responses, but they are not yet being used as experimental tools to systematically vary or "perturb" the learning situation to indicate fruitful directions for change to the experimenter or the machine itself. Currently, the time lapse between experiments is too long, and therefore opportunities to improve the educational process are too widely spaced. In production terms, experimentation is conducted on a "batch" rather than a "continuous flow" procedure.

There are so many factors or variables which affect the teaching situation that the current theories of learning, appealing in their simplicity and elegance, are probably inadequate because the simplicity is an oversimplification.

Traditionally, whenever educators and behavioral scientists have encountered a complex problem containing many interacting variables, they have dissected the problem into a host of two or three variable problems. Each sub-problem then becomes the subject for separate investigations, research papers, and often,

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contradictory reports. However, two things are almost certain: one, the original complex problem is lost sight of in the mass of sub-problem investigations; and two, the results of the sub-problem investigations can never be combined into one meaningful whole.

The elements in an automated teaching system are no less complex than those of other teaching systems, and, because automated teaching starts with the premise that teaching can be treate scientifically, there is certain to be a new rash of scientific experiments on the one hundred or more variables involved in automated teaching systems. If these experiments are not to go on inconclusively and indefinitely, we must consider some way to simultaneously improve our teaching-learning techniques (which is really our primary goal) and at the same time experiment with the variables of interest so we can make further improvements. This article will try to suggest one way in which this double objective may be accomplished.

A previous article (Roe and Moor, 1960) indicated a method for analyzing curricula, and highlighted some of the inadequacies of the current method of grouping blocks of learning into semester courses. It suggested that a much more detailed breakdown of subject matter would be desirable, and that the major difficulty in making such a breakdown is the complexity involved in the proper ordering of this greater number of "knowledge bits".

Proponents of automated teaching devices claim that mechanica or electronic modes of presenting knowledge bits will permit students to respond more or less continuously to learning stimuli, to proceed at a pace consistent with their individual capabilities and based on their individual learning history. While there is no doubt that such devices can ensure the presentation of knowledge bits in a precisely ordered fashion for optimum individual learning, they can only do so if a precise ordering has been pre-determined and the task of ordering knowledge bits is still the most crucial and most difficult part of teaching—automated or otherwise.

The proper ordering of knowledge bits for individual learning can be broken down into the following three separate functions:

a. Coding, or the statement of knowledge bits in a form that can be conveniently stored and retrieved. (This problem will be discussed in a subsequent article.)

b. Storage and retrieval of pertinent information.

c. The decision as to what sequence of information bits should be presented to each individual student.

The human mind can perform all of these functions. However, the average human mind has certain limitations in the amount of subject matter information it can store and quickly retrieve from storage (memory and recall). Also involved in the storage and retrieval problem is the information of individual student and learning factors on which to base the decision functions. When one considers the vast amount of continuously changing information, both related to subject matter and decision functions, one soon realizes that some external extension of the human mind is desirable. Such an extension of the human mind is found in modern electronic computer complexes. Indeed, such computer complexes can be broken down into the information storage and retrieval functions and decision functions.

Let us consider some of the current capabilities and limitations of electronic computers. A computer has two types of "memory" for information storage: an internal memory of limited capacity but with millisecond speed of information retrieval, and an external memory of almost unlimited capacity (size of building and cost are the important limitations), but with slower speed of retrieval. The internal memory can be reserved for decision functions (including decisions on where to "search" for information in the external memory) and the external memory reserved for storage of subject material and information on individual students and learning factors. A complete college textbook can be stored on a portion of an external memory tape so that any section of the text can be retrieved in from milliseconds up to 3 min, depending upon the location of the desired information on the tape. This maximum time for retrieval from the external memory (student waiting time) is excessive for most direct machine teaching modes. Random access external memory units, currently in production, can reduce the maximum retrieval time to one second, a wait period that would be hardly perceptible to the student. While the initial cost for storage of, say, 1,000 college textbooks would be high, the unit cost per student educated would drop below the current cost of textbooks in a short time. At this stage in the development of automated teaching programs, it is difficult to predict whether such programed material, if integrated into an overall educational system, would require *more* or *less* storage space than standard textbooks. Whichever proves to be the case, it is apparent that a 1,000-book tape library, any portion of which is available within seconds, far exceeds the storage and retrieval capabilities of the average instructor.

Now let us consider the decision function of a computer. Electronic computers evoke decisions on a "yes" or "no" (digital) basis. Higher level decisions are made by logical combinations of "yes-no" elements. Since the elemental "yes-no" choices are made in the internal memory in less than a millisecond, fairly sophisticated decisions, or logical combinations of "yes-no" can be made in a very small span of time. However, it is not difficult to conceive of decision functions which will exhaust both the internal storage capacity of any conceivable machine and/or the practical time available for making the decisions. An example frequently quoted is that of writing out all the possible arrangements of 10 persons in ten chairs (10!). This would require 3,688,800 items, a large number, but one still within the realm of computer capabilities. However, if the problem were printing out all the possible arrangements of 20 persons in 20 chairs (20!) and it took the computer one millisecond to write out each name-position, it would take the computer 500,000 years to complete the task.

Let us examine now the duties we might expect the computer to perform, and see how well these duties are consonant with foreseeable machine capabilities. We would expect the machine to store vast quantities of information in a readily accessible fashion. It has already been indicated how this may well be accomplished more handily and probably more economically than by current methods. We would expect the computer to keep a record of the student performance. Our educational system already makes a sizeable investment both in physical plant, administrative and instructors' time to keep a bare minimum of records on gross student performance. Here again, a computer could do a more detailed job and probably at lower overall cost. We would expect the computer to be able to accept (or reject) new information and to re-evaluate old information (correct and adapt). Eventually, we would want to be able to present random bits of knowledge to the computer and have the computer evaluate whether these bits should be added to storage, where they should be added, and when and to which students it would be best to present these new bits of information. This latter requirement staggers the imagination when one considers the large number of variables (about which we still know very little) which would influence the best choice. A few of these variables are the following:

a. Student preknowledge.
b. Student intelligence (past performance).
c. Level of student aspiration.
d. Learning environment.
e. Attention factors.
f. Size of learning increment.
g. Kind of subject material.
h. Reinforcement schedule.
i. Feedback.
j. Variability of learning schedule.
k. Type of response.
l. Automation apparatus.
m. Learning period.

In essence, we are asking the computer to become a continuous and vital link in the education process. We are asking it to sense and respond to everchanging subject matter, student and evaluation criteria inputs. We are even asking that it sense and respond to new variables. These are tasks which have traditionally been performed directly by human minds in more or less intuitive fashion, primarily because of the limited ability of the human mind to deal quickly and precisely with vast amounts of data. When we ask a computer to make some of the decisions formerly done by man, someone must write the rules by which the computer will make these decisions. We could even write rules for making rules, so that the computer can use the higher order rules to make the lower order rules to use in making the decisions. But no matter how high up we go in computer control levels, ultimately we must insert a human "super-control instruction". The advantage of placing the human instruction on higher levels of control is that we can make accessible to the computer large quantities of data for making the decisions on the lower levels, and thus reduce the magnitude (though not the "spirit") of intuitive decisions.

How then can a computer handle this ever-shifting multi-variable problem? Computers can perform testing of hypotheses. However, such tests generally only indicate whether or not the sample central measure (mean, mode, or median) of one thing is significantly different from the sample central measure of some other thing. If another variable becomes interesting, a separate hypothesis is formed. In each case the variables are dealt with separately. Slightly more sophisticated techniques permit one to consider a number of variables at a time, but still, one only considers the significant likelihood of equality of selected parameters or existence of interactions. Though data can be gleaned about the relative magnitude of the significant variables, this is often ignored, particularly by behavioral scientists. This may be partly due to their difficulty in combining the variables of interest in a fruitful manner. Coming back to computers, if even a modest number of readings on a limited number of variables is considered simultaneously, we exhaust the computer capabilities. If we consider only one variable at a time, we may overlook important interactions. Sometimes we take a large number of variables and find the (often approximate) functional relationships between these variables and one particular variable of interest, say, cost. In Fig. 4-3-1, if the ordinate "P" is performance or payoff, a single variable might be time, another, machine complexity. Both of these could perhaps be related to cost so that a composite function could be graphed. If this composite function has a maximum, then differentiating the function will yield a simple solution for the optimum cost-performance point. However, it is suspected that a large percentage of problems, particularly in the behavioral sciences, do not exhibit such simple optimum points. Rather, they

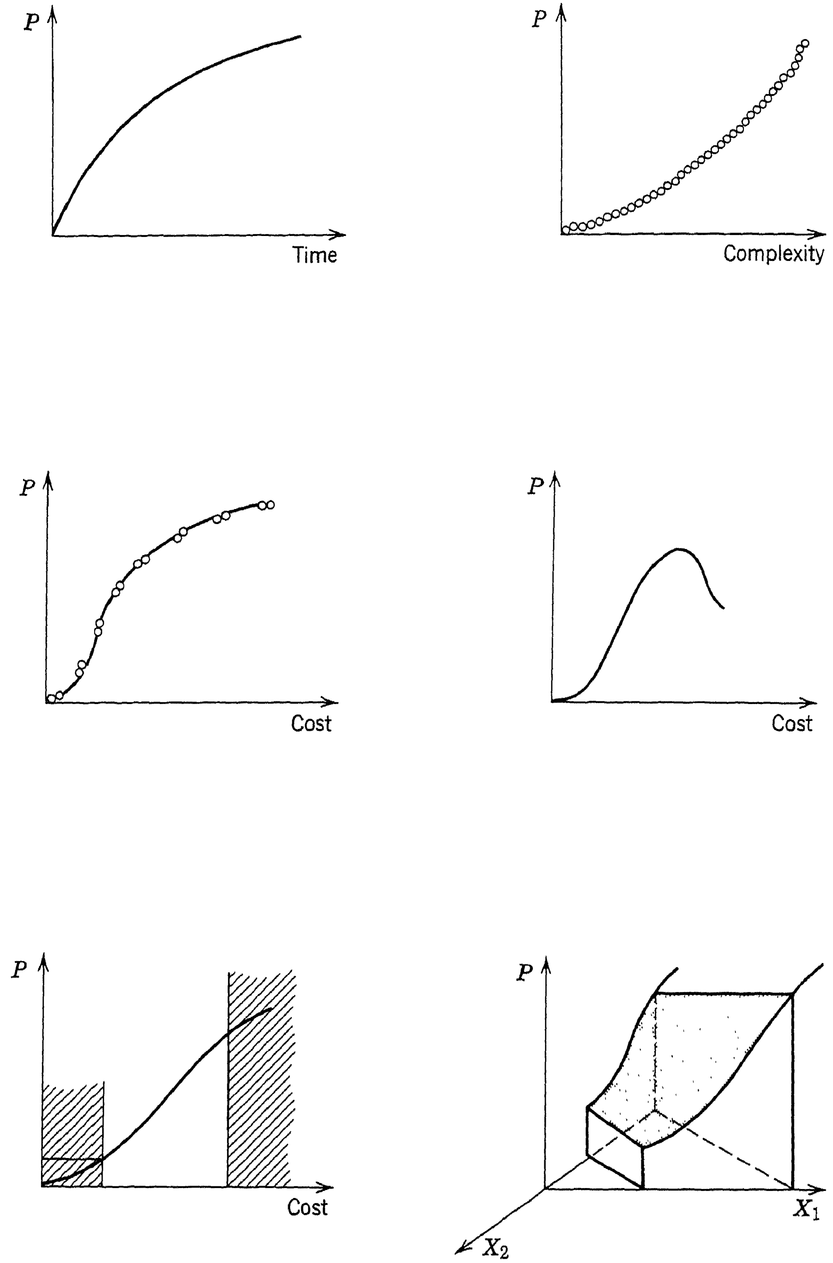

Fig. 4-3-1

may have a number of nodes or none at all. If no node exists, then we generally specify constraints or limits to the area of interest in the function space. Such a set of constraints is shown in the lower half of Fig. 4-3-1, where the upper limit might be the cost at which the system could no longer maintain itself (go-bankrupt) and so would not be around to enjoy the increased payoff. The lower limit might be the minimum cost necessary to achieve an acceptable level of payoff. Any point on the function between these constraints is a "satisfactory" solution in the absence of additional evaluative criteria. And since this function is a composite of more than one variable, in the multi-variable space we may have a multi-dimensional surface of "satisfactory" solutions. There does not appear to be a single optimum solution for such problems.

There is a technique developed by G.E.P. Box (Davis, 1956) for handling the kind of problem in which we are interested. Box considers some multi-variable response surface, as shown in Fig. 4-3-2. This response surface is supposed to represent the "real" yield or payoff corresponding to each point on the variable coordinate plane. For the sake of illustration, Fig. 4-3-2 shows a two-variable response surface, though the method is equally as valid for systems with more than two variables. This relatively simple surface is shown here merely to introduce Box's technique. Later we will show how the response surface model can be modified to meet with the requirements of a computer-controlled teaching system. In the case shown in Fig. 4-3-2, we are interested in finding the maximum pay-off point, shown by a dot on the response

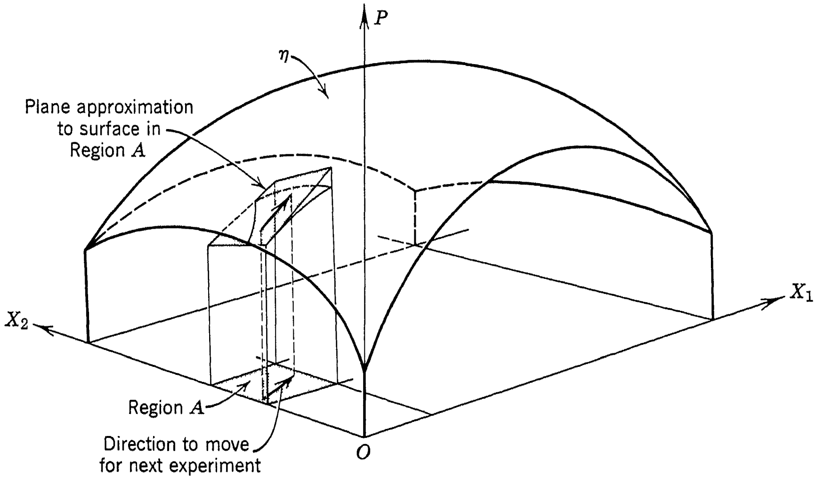
P
η
Plane approximation to surface in Region A
X2
X1
Region A
Direction to move for next experiment
O

Fig. 4-3-2

surface. However, initially, we have no idea where the surface is, nor where is the optimum point on the surface, and can have no idea until we sample from the "real world" at various $x_1 \, x_2$ points and observe the payoffs at these points. Box suggests that only a sample reading at just a few $x_1 \, x_2$ points need be taken initially, in order to estimate the slope of the surface at some region in the general area of interest. The direction of maximum slope will be the direction in which to move before taking the next few sample points. That is, one takes the path of steepest ascent, Eventually, a region will be reached within which the slope is zero in all coordinate directions, and this will be the location of the maxima (or minima).

Any surface of k variables can be approximated to whatever accuracy one wishes by using a polynomial equation including terms up to whatever degree as is felt necessary to give the desired accuracy. The general k-variable response surface would be represented by

$$\eta = \beta_0 x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \cdots + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \cdots + \beta_{111} x_1^3 + \beta_{222} x_2^3 + \beta_{333} x_3^3 + \cdots$$

Box suggests that, for the first test or experiment where one may be finding the path of steepest ascent, a first degree approximation (or plane) to the response surface could be adequate to determine the direction of maximum slope. Therefore, use

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

Higher degree terms are used when it is suspected that a first degree approximation is not adequate, and particularly when small slopes are encountered, such as in the region of the maxima.

If we are primarily interested in finding an optimum point for our system operation, or if we wish to improve our system in the quickest and least expensive way possible, it would seem that a technique which *points out the proper direction* for movement or change is more desirable than one which exhaustively defines the nature of a specific region. This is especially true if the first region is not one of interest (not near an optimum point).

In the usual analysis of variance technique, a large number of samples are taken at the sample points to reduce the error in estimating the location of the pay-off points on the "real" response surface. Box's technique takes only one reading at each coordinate point. It might be argued that this does not give any estimate of the sampling error at these points. True, but what is the sense of carefully defining the response surface in a not-interesting region? Furthermore, the coordinate system we have chosen may have been a first approximation, showing only the variables which seemed at the moment to be the variables of primary interest. The issue here is to consider the dynamic process; that is, the steps or moves necessary to improve the system, and not the extreme accuracy of estimating a given surface, particularly in a coordinate system which itself may be only a poor approximation. As one moves to regions of less change in slope, then one should consider greater accuracy of estimating the surface, and, also, should consider re-introducing some of the less important variables which may have been left out in the earlier investigations.

The mathematical treatment is also attractive, since it allows us to make decisions (in the direction of movement) without the accumulation of a large number of sample readings. This is important for two reasons: if the computations are performed by a computer, the method saves memory storage space; and, if the data are being accumulated while students are actually learning on our automated teaching system, then almost continuous modification in the ''best'' direction can be made in the teaching program, and not only after the accumulation of vast amounts of sample data. When the teaching system can change and adapt itself continuously in response to the different inputs, when it is able to increase the order in the learning-teaching situation at the expense of chaos, when it is shaped by, and in turn shapes its student (and social) environment, then we begin to have the makings of a self-organizing system (Foerster, 1959).

In Fig. 4-3-2, we have illustrated a response surface which did have a maxima. It has been previously suggested that many systems do not have maxima, and may be limited only by some time-dependent constraints. Figure 4-3-3 shows such a two-variable response surface.

Usually there is some effort (or cost) involved in taking sample measurements so that, theoretically, we can imagine a specific amount of effort (or cost) for each point on the coordinate plane. The effort amounts for all points on the coordinate plane would describe a new response surface ξ, where ξ is of the same form as η (see Fig. 4-3-3)

$$\xi = \gamma_0 x_0 + \gamma_1 x_1 + \gamma_2 x_2 + \cdots + \gamma_{11} x_1^3 + \gamma_{22} x_2^2 + \cdots + \gamma_{12} x_1 x_2 + \cdots + \gamma_{111} x_1^3 + \gamma_{222} x_2^3 + \cdots$$

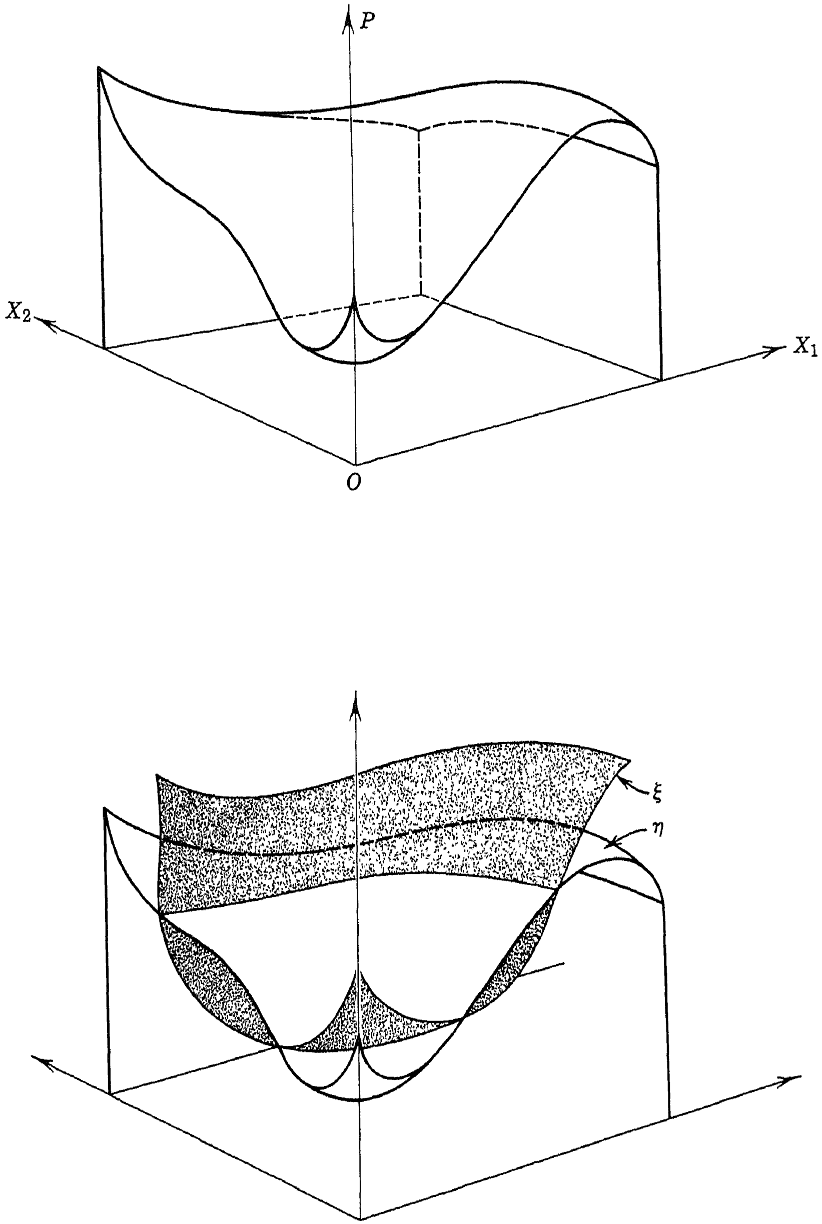

Fig. 4-3-3

If, now, we are interested in ϕ, the net payoff, and ϕ can be expressed as gross payoff minus effort, then

$$\begin{aligned}\phi &= \eta - \xi \\ &= (\beta_0 - \gamma_0)x_0 + (\beta_1 - \gamma_1)x_1 + (\beta_2 - \gamma_2)x_2 + \cdots + (\beta_{11} - \gamma_{11})x_1^2 + \\ &\quad (\beta_{22} - \gamma_{22})x_2^2 + \cdots + (\beta_{12} - \gamma_{12})x_1x_2 + \cdots + (\beta_{111} - \gamma_{111})x_1^3 + \\ &\quad (\beta_{222} - \gamma_{222})x_2^3 + \cdots\end{aligned}$$

as shown in Fig. 4-3-4. It is interesting to observe that ϕ may have an optimum point, even though η and ξ do not.

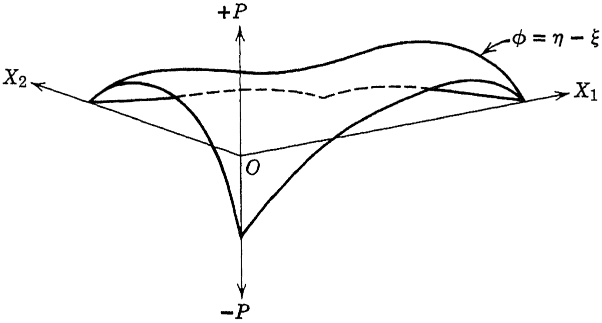

Fig. 4-3-4

The mathematics used in choosing a path of steepest ascent lends itself to incorporating other concepts. For example, utility theory (Chernoff and Moses, 1959) can be wedded to Box's path of steepest ascent by multiplying the slope of each variable (in a specific region) by a weighting function. In effect, what one is doing is changing the relative scales of the coordinate system. Another place where utility theory could be employed is in choosing the size of step to take after one has determined the direction in which to move. Here the choice is between a very long step, which may overshoot the maximum point, versus a very small step which may not move us very quickly to the maximum region.

If the weighting functions change with each sampling (or experiment) then ϕ is a function of time (or more properly, of the sequence of experiments). In other words, the response surface ϕ does not remain fixed, but changes as a result of the particular set of sample points or experiments we choose at each step. This again reminds us of one of the characteristics of a self-organizing system; i.e., one which changes in response to the environment, and simultaneously reacts upon the environment. And this is what would happen in our hypothetical self-organizing teaching system. The students would be learning, the system would be evaluating what the students learned, and as a result, changing what the students will learn in the future, and, thus, the future evaluation of what students learn.

If ϕ_0 is the state of the response surface at the beginning of the story, where ϕ is a function of x, β and γ, or

$$\phi_0\ (x;\beta,\gamma)$$

then after the first step the response surface ϕ_1 can be expressed as a function of ϕ_0

$$\begin{aligned} \phi_1 &= f_1\ \phi_0\left((x;\ \beta,\ \gamma)\right) = f_1\ (\phi_0) \\ \phi_2 &= f_2 f_1\ (\phi_0) \qquad\quad = f_2\ (\phi_1) \\ &\cdot \\ &\cdot \\ &\cdot \\ \phi_n &= f_n\ (\phi_{n-1}) \end{aligned}$$

which is a Markov chain.

Such a Markov chain is susceptible to treatment by Bellman and Kalaba's dynamic programing techniques (see references). For example, they define an optimal policy as having "the property that whatever the initial state and initial decision are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision". We can see that if Box's concept of choosing the path of steepest ascent is looked upon as a sequence of maximizing steps, then it is similar to dynamic programing. It is hypothesized that the method of dynamic programing is extensible to situations where the final state is unknown, though currently available examples have dealt with optimum decision functions, connecting a known initial state and a stipulated final state.

One difference (possibly attributable to the different backgrounds of the originators) between dynamic programing and the method of steepest ascent is that, in the former, the emphasis is on mathematical expression of the functional relationships and solution of the problem by simulation; whereas, in the latter, the emphasis is on experimental sampling and solution in the experimental or "real world" situation. Nevertheless, both techniques offer interesting possibilities for use in a computerized automated teaching system.

When searching for an optimum teaching system, one should not only relate the system of interest to the neighboring or coincident systems, but one should also recognize the arbitrary nature of system boundaries and/or variables. Automated teaching systems can be conceived on too narrow or on too large a scale. If one conceives of some non-computerized system, then the tedium of ordering the learning bits, evaluating them, keeping records on student performance, and servicing a large number of (presumably small and individually inexpensive) machines could mitigate against their widespread use. If, on the other hand, one conceives of a system which will make precise evaluation of a host of variables which may be influencing the system, then the size, complexity, and cost of the computer element of such a system may be beyond the realm of practicality.

Somewhere in between, a computerized system which uses approximating techniques to determine the *direction for change,* should prove currently feasible. As long as the initial state of the system is sufficiently large to assure its survival, its self-organizing attributes should allow it to rapidly increase its performance capabilities, and, therefore, to grow at the expense of other existing educational systems. A relatively small computerized system could start at any point in the learning sequence, and, by first focusing its attention on the analysis and ordering of knowledge items in that and adjacent areas, continuously grow (and continuously re-order its items in the light of its growth). The larger the system would become, the more powerful it would be to perform the ordering task, and the faster it could "eat" neighboring less-organized systems. Eventually, one could visualize an inter-connected network of learning centers, where the experience gained in one center would immediately be made available to the "memory" of all other centers. Instructors at any center could feed in discrete information bits at any time and in any order and these inputs would be automatically processed by the decision functions of the computer. The presentation of information would be tailored to the pragmatically determined needs of each individual student.

Nothing has been said here about replacing the human contact of student with teacher and student with student. The system envisioned above could exist with and without such contact. The choice depends on the social mores of the times. Today, the thought of having students working "face-to-face" with a teaching machine most of the school day is frowned upon (much as spending a few hours of each day in an automobile was frowned upon fifty years ago). However, the very existence and use of a large scale automated teaching system will, in time, influence our social mores, and if one feels (and this is an item of faith) that the human aspects of student-teacher and student-student relationships should be preserved, then one should hedge the automated teaching system with carefully conceived constraints.

This report has suggested that automated instruction can be initiated immediately, even though the nature of all the variables are not yet understood. The instruction process and the experimentation on that instruction process can (and almost must) proceed simultaneously.

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SECTION 5. Market Analysis and Economic Considerations

This section is devoted to the economic considerations of programed instruction. Attention is directed to the probable producers and consumers of this material, projected annual sales, marketing approaches, preparation time, cost of individual lessons, and production factors. Although exact cost figures cannot be given, the authors are able to estimate the range of values and to indicate the parameters determining higher or lower estimates.

Both the article by Kincaid and Sorenson and the Basic Systems staff memo serve to describe the potential consumer. Kincaid and Sorenson take the broad view and consider many different markets; these include primary and secondary schools, colleges and universities (including graduate schools), vocational schools, correspondence schools, and industrial and military schools. Analysis of past and current educational budgets enables the authors to project future expenditures in each of these areas.

Interest in the Basic Systems staff memo is focused on job training problems in American industry. A statistical overview indicates a growing disparity between present training capabilities and industrial needs for skilled personnel. Specific job training areas are analyzed and reveal the magnitude of the training problem, the inadequacy of conventional procedures, and the potentials of programed instruction. In addition, a detailed analysis of a representative industry, the electronics industry, indicates those job categories most amenable to programed instruction.

In his article, Wilbur Ross has analyzed the forthcoming industrial market for programed instruction and has suggested a marketing strategy for programing agencies. Programed instructional material will alleviate many industrial-training problems and, hence, will gain widespread acceptance, although this does not necessarily presage success for the companies that prepare this material. In large corporations, internal technical divisions will acquire some program-writing sophistication and will give out contracts only for special-purpose programs. In response to this contingency, programing agencies must develop acceptable marketing strategies. One possible approach involves the preparation of proprietary material of general interest to many consumers that can be inexpensively marketed for a large segment of industry.

The economic factors in constructed-response program preparation and program reproduction are discussed in articles by Klaus and Lumsdaine, by Deutsch, and by Margulies. Klaus and Lumsdaine point out that program cost is derived from preparation cost and reproduction cost. Of these, reproduction costs are greater if large numbers of users are anticipated. In this article, consideration is given to the cost of reusable and nonreusuable paper textbooks, the role of inexpensive devices, and the possibility of using microfilm.

Dividing programs into difficult, medium, and easy, Deutsch provides estimates of the different time factors involved. He considers the man-hours required to produce programs, the time required by trainees to complete this material, and the expected reduction in training time that will result. These estimates are analyzed in the light of modern industrial requirement.

The article by Margulies is directed to the training director of a company newly initiating courses using programed materials. Particular consideration is given to the problem of which courses should be undertaken first, the economic factors involved, the difficulties of measuring success, and the problems of integrating a programed course into the total training system. An attempt also is made to provide cost estimates of material contracted to a programing-preparation company.

What's Ahead in the Programed-Instruction Market?

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Our article deals with what might be called the logistics of an educational innovation—in this instance the design, development, testing, production, marketing, and maintenance of programed instruction and teaching machines. We will consider present applications and prospects over the long run for the employment of programed-instruction procedures by four broad classes of users: the regular schools from kindergarten to graduate school; business, industry, and government; the military; and individual people. Consideration will be given to present applications and prospects according to the nature of the learner, the program, the device, and the subject matter.

This article is not intended to be a market forecast in the traditional sense. It is, rather, a prediction of the impact of an innovation on an "industry"—education—of fairly well known dimensions. Some facts about current uses will be reported. Lacking facts, we will attempt plausible predictions. Inevitably, the forecast will be speculative and limited in its accuracy.

Before proceeding to a detailed discussion of the logistics of this innovation, we should re-emphasize some of the salient propositions appearing elsewhere in this book and in the literature. Programed instruction makes good sense. Teaching machines work. These generalizations are supported by experiments in the laboratory and experiences in the classroom. Programed-instruction procedures employ widely accepted principles of learning such as the following:

a. Learning motivated by success tends to be more effective than learning motivated by fear of failure.

b. Active participation by a learner usually leads to faster and more effective learning than does passive reception of information.

c. Materials and tasks that make sense to the learner are mastered more readily than nonsense materials or tasks that are not understood.

d. Immediate information or "feedback" about the nature of a good performance—knowledge of mistakes or successful results—makes for more effective learning.

Programed instruction, when properly devised, employs all these principles. But to say that programed instruction is "good sense" and that teaching machines "work" does not imply that all specific issues are resolved. We still do not know (and it will be many years before we do know) precisely the conditions under which programed instruction works best—the kinds of learners for whom it works best, the subjects that are most amenable to programing, the conditions under which the cost of programing justifies "payoffs" in learner performance. There are a myriad of more subtle issues of research interest such as strategies of programing, methods of stimulus presentation, kinds of responses to require, size of steps or frames, the utility of prompts and cues, and so on.

The many important unanswered questions regarding programed instruction and teaching machines remind us that its limits are but approximately known. It is probable that the power of programed instruction (coupled with automated teaching devices as a research tool) is barely sensed, let alone fully appreciated.

For the training specialist whose attention is snared by enthusiastic forecasts, there is some danger of viewing programed instruction and teaching machines as an answer to problems for which they may be only incidentally applicable. But even uncritical acceptance might be a blessing if it stimulates hard thinking about ways to resolve problems of personnel performance. The person who seriously considers applying the concepts of programed instruction to real problems of improving personnel performance is bound, ultimately, to come to grips with these problems in a manner that might be new to him.

The application of programed instruction demands a critical, rigorous, and tough-minded appraisal of performance objectives in specific behavioral terms so as to permit measurement of the degree to which the objectives are achieved. As the analysis of objectives is undertaken, alternative routes to these objectives might suggest themselves. Means that do not involve training—job simplification, modifications in supervisory practices, or variations in personnel selection, for example—might lead to faster or more effective "payoffs" in improvements in personnel performance. In short, the stimulus to analyze performance problems critically in search of specific alternative solutions might be one of the truly revolutionary effects of programed instruction.

OVERALL MARKET PROSPECTS

It is entirely possible that programed instruction will be the catalyst for a thorough and dramatic revolution in the mechanics of teaching. The media available for instruction today—television, tape recordings, films, self-instructional devices—are sufficiently sophisticated and powerful to be more than ancillary aids to teachers. They are capable of performing functions that historically have been performed only by teachers. They could, if we wished them to, actually replace the teacher in some of his traditional functions and, thereby, drastically modify the role of the teacher.

But, if one views programed instruction as simply a new increment in a progression of developments in the technology of instruction, then one is less likely to expect dramatic changes and the emergence of a vast new market. History seems to be on the side of those who expect an emerging market of moderate dimensions rather than an explosive growth to large dimensions. Still, one can argue that the needs of the time demand the ''great leap forward'' and that the traditional lag in acceptance of innovation no longer can be tolerated. If this latter view gains enough advocates, the prophecy of a technological revolution in educational techniques could be self-fulfilling.

Tables 5-1-1 through 5-1-4 summarize some of the gross characteristics of the markets for instructional materials. Table 5-1-1 reports enrollments and total expenditures in the regular schools for the school year 1959-60 and projected enrollments and expenditures for 1969-70.

More relevant to the question of estimating the market for programed-instruction materials, however, is Table 5-1-2, which presents estimations of expenditures for teaching aids and instructional materials. Table 5-1-2 grew from an analysis of itemized breakdowns of total expenditures by public schools. Public-school systems (K-12), for example, devote about 1.8% of all annual expenditures (including capital outlays) to instructional supplies, about 0.6% to the purchase of textbooks, about 0.3% to school libraries, and about 2.4% to new equipment (e.g., laboratory apparatus, school buses). In aggregate, these expenditures approximate 5%. Realistically, only a fraction of these expenditures can be considered as available for allocation to programed-instruction materials.

It is important to note that the estimated expenditures shown in Table 5-1-2 represent expenditures by schools. Inadequately accounted for in the table are expenditures by individual persons for textbooks. Textbooks frequently—but far from universally—are provided free to elementary and secondary-school students. At the college level, students most commonly provide their own textbooks. Note also that, in 1957, publishers grossed about $260 million from the sale of 158 million textbooks. If schools devote approximately 0.6% of annual expendi-

Table 5-1-1. Enrollments and Expenditures of Regular School Programs, 1959-60 and 1969-70 (Estimated)

Program	Enrollment[1] (millions) 1959-60	Enrollment[1] (millions) 1969-70	Total expenditures[1] (billions $) 1959-60	Total expenditures[1] (billions $) 1969-70
Elementary (K-8) (public and private combined)	32.9	39.4	11.9	15.7
Secondary (9-12) (public and private combined)	9.1	12.8	5.4	8.5
Higher education (public and private combined)	3.5	6.1	4.8	8.2
Vocational	4.0	5.0	0.2[2]	0.3[2]
Other post-secondary (private, commercial, nursing, etc.)	0.6	0.6	0.8	0.8
Totals	50.1	63.9	$23.1	$33.5

[1] Rounded to nearest tenth. Sources given in bibliography.

[2] Includes expenditures for administration; supervision, teacher, and counselor training; and instruction and counseling from local, state, and federal funds. Estimates of capital outlay unavailable.

tures to the purchase of textbooks as previously noted, this means that only about one-half of total textbook sales are made directly to schools. Thus, the total expenditure for instructional materials used in the regular schools was more nearly $400 million in 1959-60, and could be as high as $590 million by 1969-70.

It also should be emphasized that the estimates in Table 5-1-2 do not presume a decrease in the fraction of the total budget allocated to instructional staff. More than half of total current educational expenditures are personnel costs. If programed-instruction procedures were to replace teachers in any significant numbers, it is apparent that funds available for programed-instruction materials could increase radically. We doubt that this is likely to happen, at least within the next 5-10 yr. But were it to occur, it would reverse a long-term trend in pupil-to-teacher ratios—there were 37 public-school pupils per teacher in 1900, 30.4 pupils per teacher in 1930, 27.6 pupils per teacher in 1950, and 27 pupils per teacher in 1960.

Although the estimates presented in Table 5-1-2 are admittedly approximate, they almost certainly are more reliable than any we have been able to develop with reasonable effort for expenditures for instructional materials in military training. Education and

Table 5-1-2. Estimated Expenditures for Teaching Aids and Instructional Materials by Regular School Programs, 1959-60 and 1969-70

	Estimated annual expenditures (millions $)	
	1959-60	1969-70
Elementary (K-8) (public and private combined)[1]	120	160
Secondary (9-12) (public and private combined)[2]	80	130
Higher education (public and private combined)[3]	35	61
Vocational[4]	24	30
Totals	259	381

[1] Assumes 1% of total annual expenditures for teaching aids and materials.

[2] Assumes 1.5% of total annual expenditures for teaching aids and materials.

[3] Assumes $10 per pupil per year expended for teaching aids and materials.

[4] Estimated from costs of illustrative materials listed in Misc. Pub. No. 3243, List of Instructional Materials for the Supplementary Training of Apprentices and Other "On-the-Job" Trainees, U.S. Dept. of Health, Education, and Welfare, Office of Education, 1958.

training expenditures by the armed forces are a matter of public record, but they typically are reported as aggregate totals rather than as detailed breakdowns. In fiscal year 1959, the armed forces budgeted a total of $1.165 billion for all specifically designated education as shown in Table 5-1-3.

The numbers shown in Table 5-1-3 include such activities as the service academies, ROTC programs, armed-forces colleges, and institutes, service schools and extension-course programs, and various other programs of general, specialized, or technical nature for armed-forces civilian and military personnel. Breakdowns of total budgeted expenditures by item probably could be developed from subsequent records of performance. In the source from which these data were drawn, however, subtotals for each activity are qualified by notes that state, in effect, that a breakdown of the obligations for the educational and training programs into operating and administrative costs is "not feasible."

It seems doubtful that the percentage of these budgeted totals allocated to instructional materials is greatly different from the practice of the civilian schools. If the allocation is as high as

Table 5-1-3. Education Programs of the Department of Defense

Agency	Education and training budget* (millions $)
Dept. of Defense and Joint Chiefs of Staff	3.2
Dept. of the Army	309.3
Dept. of the Navy	482.2
Dept. of the Air Force	370.2
Total	1,164.9

*Rounded to nearest tenth. Source: Federal Educational Policies, Programs and Proposals, Part II: Survey of Federal Educational Activities, Prepared for the House Committee on Education and Labor, 86th Congress, 2nd Session, June, 1960.

5%, the armed forces might have expended $58 million for instructional materials in 1959-60. We have assumed 3% to arrive at our estimate of expenditures for instructional materials of $35 million.

Expenditures for education and training in business and industry are—almost literally—anyone's guess. It seems safe to say that no one actually knows how much is spent annually for training in industry. (We will be able to report a more complete estimate of this by next year if current plans materialize for a survey of training in industry to be conducted by Stanford Research Institute.) Probably the key problem in arriving at a reliable estimate (over and above obtaining the information from a dependable industry sample) is in defining accurately and unambiguously what is to be considered as "training."

Clark's estimate of $10 billion* works out to an average annual expenditure of about $135 for each person in the total labor force or about $170 for each person in manufacturing and service industries. Other estimates are more restrained—for example, $4 billion per year—but the fact remains that no estimate can be either verified or refuted with any data we have been able to find. How much does industry expend for instructional materials and teaching aids? We have estimated an average of $3 per worker in manufacturing service industries or a total of about $180 million.

The precise magnitude of the home-study market for instructional materials is unknown. A reasonable—but undocumented—guess is $60 million per year, based on the assumption that

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*Clark, Harold F. and Ruth E. Sobkov (1959) How much can the people of the United States afford to spend on education?, Unpublished report.

60 million of us spend an average of $1 each year for materials to help us in systematic home study.

Our aggregate guess of annual expenditures for instructional materials and teaching aids in major market sectors is summarized in Table 5-1-4. As our discussion has emphasized, many of these numbers can not be documented and all are estimates.

Table 5-1-4. Summary of Estimated Expenditures for Instructional Materials and Teaching Aids by Major Users, 1959-60 and 1969-70

	Estimated expenditures* (millions $)	
Major users	1959-60	1969-70
Regular schools (elementary, secondary, higher, vocational; public and private combined)	260	380
Business and industry	180	240
Armed Forces	35	50
Home study	60	70
Totals	535	740

*Estimates rounded to the nearest $ 5 million.

What share of this overall estimated total annual expenditure for instructional materials might be devoted to programed-instruction materials that are carefully developed to be responsive to the needs and wants of various potential consumers? Boehm* has estimated that as much as $100 million will be spent by 1970. Although this number seems a reasonable one in light of the total expenditures for instructional materials estimated in Table 5-1-4, 1970 might be too early a date for it to be achieved.

The following arguments persuade us that the growth of the annual dollar market for programed-instruction materials will be less rapid than the $100 million estimate would require:

a. The most dependable market sector is the civilian schools and, within this category, the elementary and secondary public schools. Diversity in the school curriculum is many times greater than the variety represented by existing pretested programs. The developmental lead-time for a programed-instruction course adequate to the requirements of a school year of teaching can scarcely be less that 18 months and easily can

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*Boehm, George A. W. (1960) Can people be taught like pigeons ?, *Fortune*, October 1960, p. 177

be twice that long. It is likely to be at least 1965, therefore, before much real choice is possible among programs with comparable coverage, objectives, and reliability.

b. Many practical issues are unresolved. The present diversity in types and styles of devices and programs permits a potential user to pick and choose, but it also prevents him from interchanging a program that is available for one style of device for another program designed for another kind of device. (This particular difficulty could be alleviated by a strong trend toward relatively cheap—say $5 to $15—devices or programs that require no devices such as programed textbooks.) Further, a prudent buyer of programed-instruction materials hardly seems likely to invest in devices before he can have some assurance that additional programs will be forthcoming. A ''programing'' industry, similar to the textbook or test-publishing industry, might emerge, and there are signs that the publishing industry itself will attempt to meet the challenge. In addition, an increasing number of teachers at all levels might learn to program. But neither of these developments seems likely to reach full flower in much less than a decade.

c. Effective resistance to the automation of instruction is a critical imponderable. Causes of resistance to the adoption of an innovation such as programed-instruction are likely to vary, but all of them will serve to delay wide-scale adoption. Some resistance will come from those opposed to change in the existing order. Empirical evidence is not likely to exert much influence on people of this sort. Others will resist adoption, on other than an experimental basis, until more of the facts are in and reliable estimates of cost and ''payoff'' can be developed. For these people, resistance could change to enthusiasm if the facts were persuasive. Historically, innovation has come slowly in education, be it in the regular schools, industry and business, or the military. For programed-instruction to herald a major revolution in the technology of instruction that results in wide-spread adoption rather than scattered islands of innovation, the traditional lag must be reduced sharply. Ten years seems like a short time for this.

PROGRAMED INSTRUCTION IN SCHOOLS

Elementary Schools

Elementary schools have yet to feel the impact from applications of programed-instruction procedures. It is estimated that less than 20% of the presently available programs for programed-instruction devices apply to elementary schools. Over the short run, one can expect that an increasing number of programs will be developed for elementary instruction in basic skills such as reading, composition, mathematics, and foreign languages. Over the longer run, experimentation likely will occur in subjects more difficult to program such as social studies, literature, art, and music.

The first programs to appear generally at the elementary-school level probably will be geared to the characteristics of the typical, literate student in the middle and upper elementary grades. But increasing attention almost certainly will be given to programing material for learners with special characteristics—preliterate children in the primary grades, children who are particularly gifted and for whom acceleration or enrichment is difficult under the guidance of a single teacher, and remedial programs for students who need to catch up or increase their ability in basic skills. Evidence appearing from research conducted at UCLA under Keislar, for example, suggests that effective programed-instruction courses can be developed for instructing preliterate children in complicated and complex subjects. Keislar has enjoyed some success in using pictures and nonverbal symbols to teach natural-science concepts to primary-level children not yet able to read.

At present, the use of programed-instruction materials at elementary levels is essentially experimental. It seems wholly likely, however, that, within the next 5 yr, programed-instruction procedures will be routine in many—but far from all—elementary school systems.

One important contribution that programed-instruction procedures seem uniquely capable of making at the elementary level is that of supplementing the background knowledge of elementary-school teachers. For example, one trend in curriculum planning at the elementary level is toward an increased emphasis on science and foreign language and earlier introduction of fairly complex mathematical concepts. Elementary-school teachers often are lacking in preparation in these areas. It seems reasonable, therefore, that well conceived pretested programs designed to supplement the teacher's resources would be welcomed in elementary schools that are willing to innovate and experiment.

A critical and unanswered question with regard to programed-instruction for elementary-school subjects is that of the availability of programs. As already noted, very few programs are now available. The future progress of programed instruction at the elementary-school level will be limited by the rate at which elementary-school teachers and curriculum specialists familiarize themselves with and become enthusiastic about the possibilities of programed instruction.

It seems likely that simple mechanical devices will be used at the elementary-school level. The programed textbook format, although suitable to middle and upper-level elementary-school instruction, are probably less effective than programs presented by simple devices. It is conceivable that whole school systems eventually might move toward the installation of computer-controlled systems accommodating multiple student stations. This prospect is remote for the next five—and probably ten—years and appears not to offer a feasible system for any but quite large school systems.

Elementary schools last year spent about $120 million on instructional materials of one kind or another, and one could expect that some of this will be allocated to programed materials and teaching machines. Moreover, it is clear that the elementary-school level represents an important frontier for the development of programed-instruction materials because so little experimental effort has been expended in that direction thus far. It is not clear who will take the initiative. One guess is that textbook publishers experienced with developing materials for elementary schools will recognize the opportunities and begin to exploit them.

Secondary Schools

Wide-scale adoption of programed-instruction procedures is likely to come more quickly at the secondary-school level than at the elementary-school level. This forecast is based, primarily, on the fact that the majority of programs currently available have been written for secondary-school students, college students, or adults. Additionally, subject fields tend to be more compartmentalized and somewhat more amenable to programing. In keeping with trends in curriculum revision and experimentation, one can expect that the earliest applications will be in the sciences, mathematics, and foreign languages. As is the case of expected developments at the elementary-school level, one can also anticipate an increasing amount of experimentation with programing in the social studies, humanities, art, music, literature, and in vocational skills.

The first programs to be used widely at the secondary-school level probably will be for average-ability students, although some experimental efforts will be aimed at students needing remedial or accelerated work of varying types. One can expect gradual development of special programs for students with particular handicaps.

Over the short run, the use of programed-instruction materials in the secondary schools will be mostly experimental.

Wide-scale adoption could lead to important shifts in school-facilities planning and to rather profound changes in the way in which audio-visual departments and school libraries are organized. School planning increasingly is taking account of developments in new media of instruction, apparently in anticipation of rather widespread adoption over the next decade.

Many of the same factors that restrain rapid adoption of programed instruction at the elementary-schools level also apply at the secondary-school level. First and foremost, very few programs are available. Among the more ambitious development efforts is that of Encyclopedia Britannica Films, which is producing, and will soon offer for sale, complete program "packages" in science, mathematics, and foreign languages. Harcourt Brace has already produced and marketed a programed textbook called "English 2600". Materials from other sources, such as the Center for Programed Instruction and Teaching Machines Inc., also are appearing on the market and can be expected to find increasing use in classroom experimentation.

Over the long run, unless an increasing number of teachers and curriculum specialists learn to prepare and refine programs, the possibilities for expansion will be severely limited. An increasing number of workshops and short-course sessions are being offered to teachers and others in the "art" of programing. As more teachers develop an ability to program effectively, it might be that an organization such as Educational Development Corporation, serving as a link between author and publisher, will be in a position to accelerate the availability of an increasing variety of programs for regular school use.

A number of other factors might inhibit the widespread adoption of programed-instruction procedures. For example, overt resistance by teachers, pupils, administrators, school boards, or the community in general can not be assessed accurately in advance. It is likely, however, that adoption of self-instructional procedures in secondary, as well as elementary, schools will be spotty and will be concentrated in those districts and areas that have a reputation for innovation and experimentation.

Colleges and Universities

The outlook for programed instruction at the college level is much the same as that at the secondary-school level. One important difference is apparent, however. Although colleges and universities are interested in applying programed-instruction procedures to classroom use, they are perhaps even more concerned with the research possibilities of teaching machines and programed procedures. Consequently, one can expect that most research-minded schools and departments of education and psychology will, in the very near future, establish laboratories and centers for systematic experimentation in programing and the learning process.

Most of the significant research in programed instruction and teaching machines is occurring in the colleges and universities. Such institutions as Harvard, University of Southern California, University of California at Los Angeles, Columbia, Hamilton, Earlham, and Oberlin have housed pioneering efforts in program development and active experimentation. It is likely that serious research with teaching machines is occurring in at least 100 colleges throughout the country.

Programs developed in college settings have concentrated, initially, on those subject fields that seem most amenable to programing—mathematics, some engineering courses, certain of the sciences, elements of philosophy (particularly logic), and language. In estimating the extent to which programed-instruction procedures will be adopted on a regular basis in colleges and universities, an important unanswered question concerns the degree of active resistance that will be forthcoming. There are indications, for example, that all faculty members do not perceive programed instruction as a blessing. The same can be said for student reactions.

From a marketing viewpoint, it is important to note that most of the programs and devices thus far employed in colleges and universities have been produced locally by the teachers and researchers who are themselves directly interested in learning more about the capabilities and limits of programed instruction. There has been some sharing of programs among faculty at different institutions and certain programs have found their way to commercial production and distribution. In spite of the exceptions, the rule thus far is that interested faculty members have produced and experimented with their own programs. From the standpoint of learning more about the capabilities of programed learning, this trend, of course, is all to the good.

Graduate Schools

Little has yet been done—or if done, has not yet been adequately reported—concerning the application of programed-instruction procedures to graduate professional training. Many aspects of instruction in medical schools, dental schools, schools of nursing, schools of law, or graduate schools of business lend themselves to wide-scale experimentation with programed-instruction procedures. The differences between instruction at the graduate level in fields such as these and the problems of continuous learning faced by professionals after leaving the university setting are so slight that one could also predict the developments of professional-level programs for postgraduate "refresher" instruction.

Vocational Schools

The utility of programed-instruction procedures in the teaching of vocational and technical skills is almost self-evident. The field provides a useful transition from applications in school programs to developments in business, industry, and the military. Some of the earliest programs developed covered such topics as computer arithmetic and techniques of computer programing. Other programs, developed primarily under military auspices, covered electronics maintenance and trouble-shooting procedures. These, as well as a host of other topics, are appropriate to much of the instruction that occurs in vocational and technical institutions, as well as junior colleges, throughout the country.

Procedural fixed-sequence skills, as well as contingent sequences, generally lend themselves to programing. These programs might take the form of step-by-step demonstrators, such as, for example, one of the Videosonic systems developed by Hughes Aircraft, or might utilize film strips or other pictorial displays (e.g., television) offering models of sequential steps in an assembly process. Such basic vocational and technical skills as key-punch operation, typewriting, shorthand, blueprint reading, and the like can also be programed.

Successful experience with programs in vocational and technical fields of relatively high occupational demand might lead to the penetration of the home-study market. An interesting possibility is the development of systematic testing procedures required for granting credentials or certificates of completion to people who successfully complete home-study programs.

PROGRAMED INSTRUCTION IN BUSINESS AND INDUSTRY

Industry is both a potential user of programed-instruction procedures and a producer of programs and devices. From a use viewpoint, the promise of programed-instruction materials offers much to many industries. For example, those industries that experience high labor turnover can gain much by substituting programed-instruction procedures for more traditional methods of training. Many training and orientation activities can be programed fairly simply, including routine assembly or repair procedures, sales techniques, or familiarization with product lines. Examples of basic skills that can be programed for self-instruction in an industrial setting are almost limitless and include shop mathematics, use of tools, parts nomenclature, safety procedures, preventive maintenance, and sequential and contingent assembly procedures. Some companies with regional, national, and international activities are reporting success with self-instructional programs that reduce the need for periods of centralized training with their high per-diem costs.

Programed-instruction procedures also suggest a number of possibilities for making training more efficient and effective in industries characterized by heavy capital investment per worker. Programed-instruction procedures seem well suited to the type of rigorous and continuous training demanded of operators of complex equipment with which the costs of errors are high and supervision necessarily must be particularly diligent.

Industry is a producer of instructional programs and devices as well as an actual and potential user. Most of the earliest program activity has centered in industries that have seen both the opportunities for use of such materials as well as the longer term prospects of their commercial development. Examples include Hughes Aircraft, IBM, Graphlex, Recordak, and Minneapolis-Honeywell. Instrument manufacturers also can be expected to develop and produce programed-instruction procedures and devices.

Another industry that is becoming increasingly active in the development of programs is the publishing industry. Wiley, McGraw-Hill, Harcourt Brace, Doubleday, Prentice-Hall, and Grolier are examples of publishing firms that have actively entered, or have announced intentions of entering, some aspect of the programed-instruction field. One could also expect that firms specializing in the development and marketing of psychological tests, audio-visual materials, and instructional materials generally would make some efforts to enter the programed-instruction materials market.

In considering the future of the industrial development of programed-instruction materials—programs and devices—it is important to recall that the device is secondary and subsidiary to the program. A teaching machine does not actually teach. It is, rather, a means for presenting the program and accepting responses from the learner. An early infatuation with the prospects of a "device market" could lead to a misinterpretation of the needs in the field. Metal fabrication, plastics, or electronics firms that anticipate entering the teaching-machine field through the production of devices will soon discover that they need to develop, in addition to their fabrication skill and mass-production ability, a capability for programing. Alternatively, they might enter into a complementary relationship with some other firm or agency to provide programs for their devices. A specific illustration of such a relationship is offered by the recently announced agreement between Litton Industries and Prentice-Hall. In this instance, Litton will be producing devices and Prentice-Hall will serve as a general source for programs.

PROGRAMED INSTRUCTION FOR HOME STUDY

An additional major market area of unknown future potential can be grossly identified as the home-study market. Here one finds perhaps as many as 60 million people who are interested in self-development and the learning of new skills or the pursuit of particular hobbies. Grolier's marketing of teaching machines and programs, through their tie with Teaching Machines, Inc., represents probably the first, and certainly the most dramatic example to date of an effort to tap this potentially large market. Content areas for programing are as broad as people's interests in learning or polishing new skills—languages, hobbies, work supplementary to regular school instruction, games and, perhaps, even psychomotor skills. The prospects of programing correspondence courses is also a very real possibility and can be expected to be undertaken with some vigor.

If increasing interest in programed-instruction materials in the home is forthcoming, it is also possible (and perhaps likely) that public libraries will serve as a depository for instructional programs and as a checkout point for instructional devices that are too costly to be owned by a single family. In this way, a family might borrow or rent a device for use and check out programs from the library much as they now check out books. It is also possible, of course, that a rental and checkout procedure could be commercialized, particularly where device costs are prohibitive.

A further possibility with implications far beyond the home-study field lies in merging the mass audience capability of television and the highly individualized feedback characteristic of programed instruction. The major technical problem to be resolved appears to be that of developing an effective two-way feedback channel between "instructor" and "pupil".

PROGRAMED INSTRUCTION FOR THE MILITARY AND GOVERNMENT

Applications of programed-instruction procedures in the military and government are not dissimilar from the applications possible both in civilian schools and business and industry.

It seems likely that uses in the military will take advantage of more complex instrumentation than is likely to be found in the schools, at least in the near future. The military already has considerable experience in the use of quite complex and sophisticated programed-instruction materials and has pioneered in their development. The Air Force, for example, has been conducting for some time an experimental program in the instruction of electronics maintenance personnel through programed-instruction procedures. The Navy also has been active, and the Naval Training Devices Center has been a focal point for some of the most interesting and important developmental studies that have thus far been reported.

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Present and Emerging Needs for Job Training

A STAFF MEMORANDUM
Basic Systems, Incorporated

This research memorandum examines the present and emerging needs of American industry for job training at wage-roll, technical, and management levels. A statistical profile of the growing demand for specialized and skilled personnel is developed. A possible systems facility, incorporating diverse training capabilities, is outlined, with reference to its potential relevance for the training of industrial employees. Although defense industries are included in this survey, the internal training needs of the military establishment, while great, are not studied. It is considered by the authors that the same training-systems facility could operate with efficiency in the military area. Although annotations have not been made in this edition, the documentation has been developed from the materials indicated in the attached bibliography.

PART I: Survey of Industrial Training

STATISTICAL OVERVIEW

The several billions of dollars now being spent annually by business and industry on job training will undergo a substantial increase in the near future. In the next decade and a half, the labor force will increase faster than the population: from 73.6 million to 95 million—an increase of 34%. This is a greater increase than in any other 15-year period in U.S. history. It means that, by 1975, one out of every two workers will have entered the labor force during the previous 15 years.

At the same time, the proportion of skilled jobs is rising even more rapidly. Within the total labor-force increase of 34%, the number of white collar workers will increase by 57% and the number of blue collar workers by 25%. In this latter group, the largest relative growth will occur in the skilled worker category: from 3—11.5 million.

Among the professional and technical groups, 5.25 million additional persons will be needed because of national growth, and five million more as replacements. Professional and technical personnel represent the fastest growing group in the postwar period. During the next 15 years it will increase 2 1/2 times as fast as the labor force. For example, 650,000 scientists (or double the present number) will be needed in 1975, as will two million engineers (as opposed to the present number of 850,000). This, of course, will condition a very rapid rise in supporting technicians, such as engineering aides and electronic specialists.

In the craftsman group, 2.5 million additional individuals will be needed because of total national growth, and 5.5 million for replacement. (Example: electricians need to increase by 190,000 from growth, by 200,000 as replacements.) It is very doubtful that present training activities can meet this need, e.g., present apprenticeship programs would train only 10% of the eight million total required.

In the sales-worker group, a two million increase over the four million individuals employed in 1957 will take place. These individuals will need instruction in sales techniques, and the increased complexity of equipment and introduction of new materials will demand even more technical training. The number of clerical personnel will increase from 7.2 million to 13.7 million despite advances in automation.

In terms of age groups, however, there will be a decrease in the number of male workers between 25 and 44 years old. This intensifies the total training problem since this age bracket usually supplies a large proportion of foreman, highly skilled workers, middle management personnel, and technicians. This means, of course, that workers outside of this bracket will have to be trained or retrained for a greater proportion of these important jobs.

The U.S. Department of Labor estimates that by 1965 we are going to need 137 professional and technical men, 122 managers and officials, 127 clerical and sales people, and 122 skilled craftsmen for every 100 we have today (see Table 5-2-1). Although our population will increase by 18 million people in 1965, the greatest proportion of this increase will come in the age groups that are above 44 and under 25 years of age. Accordingly, there will be no increase in the number of men who are in what the Department of Labor calls the ‘‘prime’’ working ages between 25 and 44.

There is at present no national survey of training establishments in the United States, although the Bureau of Labor Statistics has begun work on one. There is, however, a survey of industry in New Jersey, undertaken as a pilot project of the national survey. It should be possible to extrapolate a good deal from these figures, given in Table 5-2-2.

Table 5-2-1 Employment by Major Occupational Group, Actual 1957 and Projected 1965-75[1]

	Employment in millions[2]							
	1957		1965		1970		1975	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	65.0	100.0	74.3	100.0	81.2	100.0	88.6	100.0
Professional, technical, and kindred workers	6.5	9.9	8.6	11.6	10.3	12.7	12.3	13.9
Managers, officials, and proprietors (except farm)	6.7	10.3	7.8	10.5	8.6	10.6	9.6	10.8
Clerical and kindred workers	9.2	14.1	11.0	14.8	12.3	15.2	13.7	15.5
Sales workers	4.1	6.4	4.9	6.6	5.5	6.8	6.1	6.9
Craftsmen, foremen, and kindred workers	8.7	13.3	9.9	13.4	10.9	13.4	11.9	13.4
Operatives and kindred workers	12.5	19.3	14.0	18.8	14.8	18.2	15.6	17.5
Service workers	7.6	11.7	9.1	12.2	10.1	12.5	11.3	12.7
Laborers (industrial)	3.7	5.7	3.7	5.0	3.8	4.6	3.8	4.3
Farmers and farm managers and farm laborers and foremen	6.1	9.3	5.3	7.1	4.8	6.0	4.4	5.0

[1] Source: 1957 data from Monthly Report on the Labor Force, U. S. Department of Commerce, Bureau of the Census; 1965-1975 data projected by U. S. Department of Labor, Bureau of Labor Statistics.

[2] Percentages are based on unrounded figures.

Table 5-2-2. Survey of Training in the Industry of New Jersey

Size of company (number of employees)	4-19	20-99	100-499	>500
Number of companies surveyed	26,886	8,484	1,857	319
Percent of companies of this size	70	20	5	<1
Number of companies with training	2,972	1,947	920	241
Percent of companies with training	11.1	22.9	49.5	81.5
Percent of companies with training departments	4.2	17.4	17.7	41.2
Percent of companies with training by foreman-supervisors	42.2	13.5	31.5	38.1
Percent of companies with training by personnel manager or staff	52.9	55.0	46.1	19.5

Out of a total New Jersey employment of 728,531 by companies sponsoring training for production, about 70%, or 514,316, were employed in manufacturing establishments. These establishments represented approximately 24% (9,419 out of 37,416) of all companies.

Within the manufacturing group, 241 out of 9,419 companies—or about 2% —employed 500 or more individuals. This 2% employed a total of 315,408 individuals, or 60% of the total of 514,316 employed in the manufacturing group studies. Thus, while representing less than 6/10 of 1% of the total, these 241 manufacturers employed about 42% of all workers. Of this group 82.6% sponsor some form of employee training.

At the time the survey was made, 21,764 employees were enrolled in training programs of varying duration in the group of manufacturers employing 500 or more people. This was about 50% of all industrial trainees in the state. 1,207 training operations were used by this group, an average of about 18 employees per operation.

Out of a total of 728,531 employees (11.3%) employed by 6,099 establishments sponsoring training (16.2% of all industrial establishments) 82,740 employees were currently participating in training programs. These establishments sponsored 15,873 training programs. With the average number of trainees per program at five, present methods appear uneconomical—particularly from a systems standpoint.

More than half of all establishments supplemented internal training with that offered by some outside facility. 41.5% of all firms used no outside facilities, and 58.6% of the manufacturing group used no outside facilities. 68,740 employees were currently enrolled in 11,813 in-company programs, an average of about 6% per program.

In short, a survey of this typical manufacturing State reveals that job training is today almost nonexistent among smaller companies, though their need for it, as can be shown, is great; that training procedures, in those companies where they do exist, are poorly rationalized, usually involving minuscule student populations at any one time; that companies already committed to training are the large ones which, as other analyses show, usually have sufficient funds to support more efficient methods as they become available. In terms of input-output analysis—particularly in view of the total amount of training actually required—the present approach appears uneconomical and ill designed. Whereas human teachers and conventional techniques are excessively costly for small and scattered student groups, programed instruction in a behaviorally designed learning context promises far more efficient and economical employee training.

REPRESENTATIVE TRAINING PROBLEMS

High-Turnover Jobs

A number of important job categories requiring mastery of specialized subject matter are characterized by very high turnover. For example, there are more than 196,000 life-insurance agents in the United States who are employed full time. In addition, there are 100,000 property and casualty insurance brokers. Turnover is estimated to be as high as 70% annually. At the same time, most companies maintain elaborate, lengthy training programs for these men and there is expected to be still greater emphasis on in-service training of agents. This pattern extends to other job categories such as registered securities representatives, mutual fund salesmen, airline clerks, door-to-door salesmen, bank service personnel, lower management, etc. The subject matter taught in each case is relatively static and involves working with large student population.

Retraining Following Automation

Retraining will probably continue to be increasingly significant in the coming 15-year period and often involves skilled and semiskilled workers displaced by automation in continuous process production. Attempts to retrain these workers are being carried on by industry and by government.

An example of industry effort is the Armour & Co. program worked out with the Amalgamated Meat Cutters and Butchers, and the United Packinghouse Workers. Armour allocated $500,000 for a program to train "qualified employees in the knowledge and skill required to perform new and changed jobs so that the present employees may be utilized for this purpose to the greatest extent possible." Symptomatic of the inadequacy of the total project, however, was the fact that 65% of the displaced workers applying for the program were eliminated by screening tests, as not possessing adequate prerequisites for the training involved.

Under a section of the recently passed Federal depressed areas bill, money is provided for the organization of retraining projects on a community level. Projects are under way in Hazleton, Pa., and Lowell, Mass. Much more comprehensive provisions for retraining are contained in the Clark-Holland bill. Under its terms, the Federal Government will pay up to 100 per cent of the cost to the States. Under terms of agreements worked out between Federal and State Governments, State agencies may use public education facilities or, if such facilities are not adequate they may arrange for training with private institutions.

Commenting on the bill in a statement to the House Committee on Labor and Education, HEW Secretary Ribicoff said:

> "...technological change, innovation, automation and industrial mobility displace many people who want to work and who are physically and mentally able to work but who cannot work because they lack the knowledge and skills which they need. Moreover, it appears that these changes ... will increase at a much more rapid rate than they have in the past ...
>
> "We must shift toward more training for technicians, distribution, sales, personal and community services and other areas required by our national manpower needs ...
>
> "Of the five million unemployed, about one-third are under age 22 and half of these haven't held a job since leaving school. Most are unskilled.
>
> "The older worker constitutes a special need for training and retraining. As of April, 1961, the Department of Labor reported that 31% of all unemployed were over age 45, and 35 of those unemployed for 15 or more weeks were over age 45."

Apprenticeship Programs

Apprenticeship programs exist today mostly in older crafts and industries. But even among such groups as plumbers, printers, machinists, etc., this system will provide only about 10% of the craftsmen needed by industry in the next 15 years.

Often, apprenticeship systems are financed by an employer or industry associations, in collaboration with trade unions. Widespread adoption of apprenticeship programs has been inhibited by their cost to management despite the fact that they provide an assured supply of skilled craftsmen for the company sponsor. Apprentices must be paid at a very high rate to maintain their motivation to finish programs which in most cases run from 4-8 years. Because of its length, apprenticeship strengthens worker ties with the company and cuts down on turnover. Nonetheless, learning time seems excessive by even the most inefficient instructional standards.

This relatively small aspect of industrial training accounted in 1958 for only 178,000 young people in programs meeting the standards of the Federal Bureau of Apprenticeship. In contrast, the Soviets claim to have trained 7.5 million young workers as skilled hands in 500 narrowly specialized trades during the last 15 years; in 1955 alone, they turned out 92,000 engineering technicians—which is seven times as many as we trained in the same year. Clearly, job training even for older skills must be overhauled, shortened, and made more effective.

Continued Training for Professional and Management Groups

According to the U.S. Office of Education, Bachelor's degree graduates may reach a total of 10 million in the 1960-75 period. It is estimated that professional and technical degrees will account for 60 to 75% of this total. Thus, 3-4 million professional and technical jobs will have to be filled by persons without college degrees. This clearly implies that existing programs for upgrading skills within industry will be greatly enlarged and many others initiated.

Of all professional groups—and, in fact, of all occupational groups in the labor force—engineers will require the most extensive and continuous training. In 1958 there were approximately 850,000 engineers in the United States, three-fourths of them employed in private industry. (Those employing the largest numbers were electrical equipment, aircraft and parts, and machinery industries.) It has been, and will continue to be, one of the fastest growing occupations. Losses from retirement and death were 10,000 in 1958 and are expected to gradually rise in the next 15 years. 35,332 Bachelor's degrees in engineering were granted in 1958 and this number is expected to double in the 1960's.

The need for continual training of this key group of personnel has already been recognized by management and teaching authorities in the field. Dr. Chester J. Kishel, head of the Industrial Engineering Department of Fenn College in Cleveland, noted that engineers fresh out of the classroom are commanding high salaries because those who graduated a decade ago are obsolete, remarking: "For an engineer to keep up to date on developments he would have to spend 30% of his time in study."

Mr. John Phillips, of DuPont's engineering division, offered a similar comment. He said effectiveness of engineers now in their thirties and forties is severly reduced by lack of knowledge and competence in new technological developments. Schools run by computer companies, for example, are filled with industrial engineers catching up with new developments.

Although it is estimated that the managerial group will show the smallest rate of increase in the 1960's, there will be a three million increase over the present force of 6.7 million. As in the case of other occupations, this group will need to possess far more knowledge of a far broader kind about a widening variety of processes and situations. Beyond maintaining competence in technical areas, executives, of course, need knowledge of developments in business organization, economics, labor contracts, and still more general disciplines.

Continuous Training for Other Job Categories

With the increasing number of new products and processes, most workers will continue to be trained throughout their working life. The electronics industry is a striking example. There were 170,000 electronics technicians employed in the electronics industry in 1958, and this number is rapidly expanding. (In addition, 250,000 members of the armed forces are trained in electronic maintenance.) The need for thorough training extends beyond this skilled group to assemblers who are constantly confronted with new designs. Short product runs, involving entirely new technical problems at frequent intervals for an increasing labor force, intensify this problem. While many companies now attempt to meet the training need, others, with substantial dollar volume but small work forces, would like to do so if costs could be rationalized. In the closely related field of computer manufacturing, greater efforts are being made in the face of a similar problem. All computer companies have substantial training programs; IBM leads with an annual education budget estimated to be over 45 million dollars. Similarly, the Bell System and Western Electric complex maintains continuous training for most of its 770,000 employees.

Industrial salesmen or sales engineers sell mainly to other business concerns. These individuals, primarily men, require exhaustive knowledge of their own firm's products and almost equally comprehensive knowledge of the operations of the client. These salesmen may spend weeks or months analyzing client operations and working with his own company's research department to find client needs which his products can meet. Furthermore, salesmen are frequently called upon to train client's employees in the use of his firm's product after sale is made. Many corporations have extensive training programs for such salesmen which last two or more years.

Pharmaceutical companies, for example, have a critical need for instruction to enable their detail men to master the complexities of new drugs and biochemical preparations. This is doubly vital because it has been estimated that 80% of physicians' knowledge about new drugs comes from the medical detailer. Producers of primary metals, machinery manufacturers, plastics suppliers, and the industrial chemical industry, all need salesmen who have a substantial knowledge of their own product lines and the processes of client firms. The salesmen for computer manufacturers are a prime example. Other areas of electronics need high quality technical selling in a range that comprehends components for missiles and jet aircraft to parts for tractors and washing machines.

Maintenance technicians keep complicated equipment representing a high capital investment on an operational basis. Accelerating technological complexity puts an unprecedented demand upon them for both scheduled and unscheduled maintenance. As George Baldwin and George P. Schultz of the MIT Industrial Relations Department have suggested:

> "...the new technology takes over most readily the materials handling and completely routinized machine operations and tends to emphasize, as far as the average plant workman is concerned, jobs directed at 'keeping the process going because we just can't afford to chase all over the factory for a maintenance man when something goes wrong. He's got to be right there and he's got to know something about electrical and hydraulic problems, not just mechanical.' So the proportion of maintenance people is likely to increase as well as the skill required of them...Mechanization may indeed have created many dull and routine jobs; automation, however, is not an extension but a reversal of this trend: it promises to cut out just that kind of job and to create others of higher skill... The training—or the educational job implied—will obviously become more difficult and more important as the speed of innovation increases... For example, when three or four types of grinding opera-

> tions, each now representing a separate job classification, are tied together by automation, one man will be able to operate the integrated grinding line. This man must have a generalized knowledge of grinding; and his changed, broader job classification is likely to carry more pay than any of the old grinding occupations... As a standard for continued employment, 'ability to learn' would gradually replace 'ability to do' the job."

The introduction of automated machinery in production, eliminating human efforts at the base level of operators or assembly workers, but increasing demand for increasingly skilled maintenance technicians, is being felt in food and beverages, paper and allied products, tobacco processing, petroleum, chemicals, as well as in industries producing the automated equipment itself, such as machine tool and electronics. A DuPont executive, confirming the MIT report, remarked that plumbers, electricians and mechanics have been replaced in chemical production by "process mechanics" who can function across established trade lines.

The efficiency of present industrial maintenance is difficult to estimate, for few figures are available. However, military experience with similarly complex equipment may be relevant; Hall has shown that only 33% of Navy electronic equipment was operating satisfactorily in 1950, and that 9% of electronic equipment in Fleet Units was inoperative and 65% operating poorly or improperly in 1955. The problem of millions of failures was serious not only because of the cost in billions of dollars, said Hall, but also because of the decrease in operational effectiveness. Among examples he cited were certain types of complex airborne electronic equipment requiring over three hours of maintenance for each hour of flight; that one-third of Air Force operating cost is for maintenance and one-third of Air Force personnel are engaged in this activity, although over half of Air Force maintenance is done by contractors. Additionally, it was pointed out that the cost of maintaining electronic equipment in the Air Force was about twice as much per year as the initial cost, that maintenance during the life of Navy equipment is ten times initial cost. While maintainability can, in some instances, be dealt with at the design stage, "unscheduled" problems are not alleviated by such techniques as self-test diagnostic-routine circuits and check-out fault-isolation programs.

The makers of automated equipment found that maintainability of electronic components, systems and subsystems involves many factors, among the more significant being systematic job analysis, equipment design for maintainability, realistic technical training, practical job instruction devices and high-speed field modification information communications. At the 1956 Air Force Fire Control Systems Training Conference, it was demonstrated that, while the maintenance of complex electronic systems was not beyond the learning ability of most trainees, imparting these skills to the learner was fast-exceeding the teaching abilities of the instructors.

Preparation of Manuals

About 2.8 billion dollars are spent each year for the preparation of manuals. The "Bell System Procedures" are an example of a comprehensive set of materials covering, in minute detail, specifications for every component, device and task found in the total technology of the telephonic communication industry. In design and use, however, present industrial manuals appear to compromise unhappily between training needs and the requirements of reference works. Much like textbooks in academic training, industrial manuals are ambiguous in function. They combine elements of a "rule" book, of a teaching implement, and of an encyclopaedic compendium of facts and figures. Much of the money now budgeted for manuals is likely to be allocated to direct training as the need for efficiency in skill dissemination is more widely felt. Job manuals are now invariably written by engineers and scientists who are the creators of the equipment described, or by professional manual writers who are, by education, lower-level technicians; the manuals are therefore usually poorly organized from the standpoint of learning psychology, and fail to recognize the special needs of operating and maintenance personnel. These materials could be vastly improved, and given greater performance for each dollar spent on their preparation, if learning psychology were systematically applied.

A CASE STUDY: TRAINING PROGRAMS IN A LARGE ELECTRONICS CORPORATION

The representative training problems just described and others are best seen in the specific model of a working industrial organization. We here describe the training efforts involved in the sale of equipment of one out of four divisions in one group of the corporation's domestic operating divisions. The division employs about 5,000 persons, 3,000 in the laboratory, 2,000 in the factory.

On-Line or In-House Training

This training effort is headed by six administrators who supervise the efforts of 40 instructors, who have no other function inside the company. Most of the instructors are part time; all of them are from outside the company.

Training Categories

The following are the two major job-category breakdowns:

a. Administrative. Executives, managerial and supervisory personnel. The lowest category here, that of Supervisor, is salaried at about $18,000.

b. Technical Engineering Personnel, Technicians. This group is composed of technicians without a degree who need to have thorough and advanced engineering training despite their job classification as wireman, trouble shooter, etc. Included above are draftsmen who prepare, develop and modify drawings in the laboratory, and shop personnel in various craft categories.

It is estimated that about 80% of personnel in training are in group b and about 20% in group a. All students are paid full rates for time in training. It is estimated that the average salary in group a is three times that in group b.

Company Courses

About 150 courses—all formal classroom training—are given to both groups. The *administrative* group takes courses entitled management training, executive development and supervisory training which consists of such subject matters as management-labor interaction, preparation of company forms, report writing, administrative and company standards, etc. These courses are mandatory. The *technical* group studies advanced technical subjects, mostly at an engineering curriculum level. A number of courses are given all employees when they first enter the company. These are mandatory. The rest are voluntary.

Courses in Universities and Technical Institutes

Any employee of the corporation can take any course or degree for which he is qualified and which the company approves as relevant. The company allows the student 3-4 hours a week with pay for this study. It also reimburses him for all tuition, 50% paid when the study is begun and 50% when he receives the degree or completes a given curriculum.

Direct Training

This training is conducted by the division as part of the contract with a client, which requires that the company be responsible for adequately trained personnel to operate the product. Products of this division are various kinds of electronic systems.

The division meets this responsibility by furnishing personnel from its own staff, by hiring outside personnel or by training personnel from the client company or Armed Forces unit. All the personnel from whatever source have to go through a training system designed to provide the human capabilities to combine with the electronic system belonging to the group. In performing this job, the division combines with another division of the corporation whose exclusive function is the preparation of training systems, including preparation of manuals, etc.

Training of Instructors

In direct training efforts the first task is the training of instructors who will in turn train the personnel who will operate and maintain the electronic system. This group is formed from the technical staff of the division (designers, engineers, etc.), or is hired from outside the corporation.

School Facilities

School facilities are set up for each training effort, sometimes using client's facilities, sometimes those of the division.

Scope and Number of Such Training Efforts

The training division of the defense group is at present handling training for four military contracts. These all involve systems for the Air Force devoted to early warning, integrated communication, control systems, etc. One of these training efforts is budgeted at $6,000,000. These programs are devoted solely to teaching technical personnel how to maintain and operate various parts of the major and minor subsystems which make up a system.

Training Project

Following is the example of the organization of a training project for a major subsystem which is one of three major subsystems and two minor subsystems which make up one system of the four presently being handled by the training division. Total cost for this single subsystem is budgeted at $250 to $400 million.

a. Training of instructors. Eighteen instructors. Training time: 10 months. Subject matter: Operation and maintenance of subsystem. This involves highly advanced categories as of electronic knowledge at engineering level.

b. These instructors then train 320 persons—in this case all military personnel.

c. This training involves some simulation but is primarily classroom training, academic in nature. Objective of the training is to create experts with very broad backgrounds in electronics and also specific knowledge of the subsystem structure who can perform the trouble-shooting function which is highly creative, conceptual and not a rote task. Also, a good deal of computer programing is taught.

d. In this case, simulation involves the use of a giant computer group and accessories, creation of which is itself a major job. This simulation of the actual system is then used both to train personnel and to locate areas where electronics must be adapted to human factors in the subsystem. Subsequently, adjustments are made in the actual subsystem.

e. Manuals are written, of course, prior to the above training, but they, too, are sometimes changed in response to experience with them in the training process.

f. A large number of courses are given which take from six weeks to six months.

A Sample Student and What He Must Know

The student's job will be transmission equipment maintenance supervisor. The Air Force Specialty Code requires that he have 15 years training and experience in transmission equipment, its installation, maintenance and operation. He must understand electronics, binary mathematics, computer programing, pulse techniques and logical and digital circuitry. He must be familiar with transmission equipment design and modification. He must be thoroughly experienced in installation, operation and maintenance of transmission equipment such as Modems, Cryptos, automatic exchange equipment, leased line switching equipment, fault and facilities control equipment, line unit equipment, clock signal generating equipment, etc. He must be able to operate all the kinds of test equipment that are used with the above.

It is extremely unlikely that this type of trained person is found already prepared. He must be given training covering the above which includes: Intermediate electronics, Boolean algebra, digital and pulse circuitry and complete orientation in the parts involved in the subsystem both as to operation and maintenance.

Critical Nature of Systems: Reliability Factors

All of these systems are built at least in duplex. If they are complicated to operate and maintain, and breakdowns are projected, then they are built in triplex or quadruplex and so on depending on degree of frequency and length of repairs. If training can increase human factors efficiency in maintenance, the systems duplication can, of course, be reduced. A reduction in one system from quadruplex to duplex eliminates $38,000,000 for the computers alone.

The maximum time allowed for a major subsystem to be not available or not on the air in this case is 1/10 of 1%. About 10% non-available time is allowed for one in a quadruplex system. The mean time allowed for repair of a part in electronic military systems of this kind is under one hour.

Location of Systems and Resulting Salary Scales

Many of these systems are located in remote regions such as the polar region. Civilian personnel who receive $10,000 a year in the United States are paid about $27,000 in these areas. Frequently, it is impossible to provide military personnel with adequate prerequisite training and civilians must be hired.

Training of Salesmen

There are 15 salesmen for the division. They are distributed over the country. Their chief function is information gathering. This requires them to have a very broad technical background and to be able to analyze and report on systems needs in the military and industry and to give specifications which the designers and engineers can follow.

These men need training, first to fill out gaps in their technical background and keep them up to date; second, to enable them to gather the information adequately, in the proper sequence and quickly enough to meet lead times. These salesmen or contract men are, of course, essential to the business. They are paid in a range of $13,000 to $15,000 a year.

Language Training for Administrative and Engineering Personnel

Fluency in various languages would be most helpful and useful to this particular corporation as it has many overseas divisions. Language training could usefully be given to executives, supervisors, managers, engineers, etc. who are both American and foreign nationals.

PART II: Behavioral Learning Design for Industry

OPTIMAL LEARNING DESIGN

Programed instruction, as has been repeatedly demonstrated and as has been documented in the scientific literature, offers a rapid, flexible, economical and efficient solution to the problems described above. Tested applications of learning theory delineate the following elements of efficient curriculum design:

a. Creation of a formal response mode to ensure active learner participation.

b. Presentation of material in discrete units with deliberate and small increments forming a cumulative sequence.

c. Feedback in the form of response evaluation immediately following each micro-unit.

d. The instructional cycle is, except for special cases, self-pacing.

The usefulness of constructing such sequences on an empirical basis was first fully stated by B. F. Skinner in 1954. Many of Skinner's conclusions were prefigured in the experimental foundation layed by researchers such as Pressey (1926) and the still earlier work of experimental behaviorists such as Thorndike. Intensive research along the specific lines suggested by Skinner took on an institutional pattern in the twelve years following Skinner's first paper. Research into programed instruction has received support from Air Force and Navy laboratories, the Ford and Carnegie Foundations, and the United States Office of Education; experimental projects have been carried out at nearly 200 schools and universities. The final impetus of popular interest, having been inspired by display-device manufacturers—with a somewhat distorted emphasis on device characteristics rather than on curriculum design—developed during 1960, although full commercial exploitation was still a year or two away. One of the first areas to suggest itself for full scale application of programed instruction is business and industrial training where the advantages of the new method spell themselves out with particular consistency and relevance. In this context, where goals are specific and benefits measurable, the feasibility of programed instruction can easily be demonstrated and its introduction greatly facilitated.

Universal Advantages of Programed Instruction

Programed instruction provides a mastery of subject matter that defies comparison with the results of any other method of instruction and greatly increased speed of learning. Programed instruction, though still in an imperfect stage of development, reduces learning time from 50 to 33% of that consumed in traditional methods of instruction. Rigorous evaluation examinations reveal major improvements in skill mastery and comprehension.

With programed instruction, training costs can be reduced and accurately measured. There is presently no objective and practical way to measure the efficiency of a particular textbook or instructor. A program can be subjected to rigorous tests on a variety of sample populations. Its cost is explicit and can be averaged or amortized like any other cost. It is not hidden in overhead or spread out over part-time efforts of supervisors, engineers, or complicated deals with outside universities, vocational schools and technical institutes. Radical cost reductions can be achieved. With present training techniques, a very limited number of employees can be trained at any given time. This means that the operating costs and overhead of instruction is very high per worker especially if there are many different specialists. Obviously, programed instruction could cut these costs and isolate them.

Programed instruction overcomes geographical separation of trainees. Trainees who are spread out geographically either in separate divisions of a corporation of in sales territories do not have to be transported and maintained at company expense in some central training center. Programs can be mailed to them and tests administered by division managers.

Programed instruction reduces extensive screening operations. With programed instruction, the extensive screening operation now undertaken by personnel departments of many corporations can be reduced. Easier and more efficient training can make up for deficiencies in technical knowledge. This also allows executives responsible for hiring to employ applicants they feel are strong in other areas such as personality and attitude.

Programed instruction eases the shortage of good instructors and reduces instructional cost. In industry as in the schools, there is a shortage of teachers and an extreme shortage of good ones. In his description of the organization of the Lockheed training program, Karl R. Kunze, the company training director said: "Lockheed found itself in a position comparable to neighboring school systems—it needed 'education' and lacked educators. The skilled man who could instruct was needed in two places at once—his own work station and the training class." Such problems can now be overcome through specially constructed programs. It would also seem that far more thorough and extensive training could be given, and the supervisory load eased, with programed instruction. Companies where no training department now exists would especially benefit. Training departments themselves could be reorganized, their cost reduced and their results precisely measured with programed instruction.

Programed instruction enlarges the content of training programs. As a corollary, companies would have the option of greatly increasing the content of programs and depth of subject matter taught. Standard programs could be devised which would be economical for smaller companies employing less than 99 employees and their training programs thus greatly extended and strengthened.

Programed instruction adjusts to individual differences in ability, formal education and job categories. Differences in degree of ability, formal education and job category divide industrial employees into a wide variety of student groups—far more than exist in school populations. In addition to these differences, seniority gives promotional priority in many cases to older workers who tend to have a lower level of formal education. In some cases, union contracts freeze men into jobs whose descriptions have been radically upgraded by technological change, (i.e. electronic assemblers). Many companies follow and others would prefer to follow a policy of promotion from within to maintain high morale. They are frequently prevented from doing so because employees lack knowledge and skills. Many industrial employees have been educated or have educated themselves informally in a process of work experience, correspondence school courses, instruction from supervisors, moving from job to job, etc. Even those possessing a roughly identical background, vary widely in their knowledge of and mastery over a given subject matter. Again Mr. Kunze: "Another problem had to do with the wide range of individual differences in ability to learn among those who entered the early training programs. These differences were so great that the brighter and more capable were unmotivated and others much less gifted were confused."

Industry Awareness of Programed Instruction

Public awareness of the field of programed instruction was stimulated by a number of popular presentations appearing in magazines such as *Time, Saturday Evening Post, Newsweek, Pageant, the New York Times Magazine,* and others. At the same time, of course, specialized pieces and monographs continued to appear in the field; emphasis on applications to business and industrial training grew with the appearance of articles in such periodicals as *Industrial Relations News, Fortune, Journal of the American Society of Training Directors, Fire Engineering, Industrial Research, Factory and Personnel Journal.* This generated increasing interest in the practical use of programed instruction so that workers in the field received frequent and numerous inquiries. Seminars and speakers throughout industry and business have begun to address attention to the new technology. Instituitional bodies such as the American Management Association or the Electronic Industries Association have been giving extensive consideration, through conferences and special committees, to many of the topics detailed in this memorandum. Several of the largest industrial, among them DuPont, IBM, Eastman Kodak, Hughes Aircraft, Polaroid, and General Dynamics have initiated studies and experimental tests which have given them a fairly sophisticated grasp of, and an affirmative attitude toward, the new instructional system. Companies in close touch with the military are naturally conscious of an emerging technology which has been heavily funded and closely examined by the defense establishment.

Company funds and company training programs will not be committed to programs, however, on any full scale before prospective users have received practical demonstrations of the method's merit. Probably the most convincing approach is to organize a small-scale pilot project within the given company. Promotional materials, citations of success elsewhere, scientific documentation, are all much less persuasive.

Even initial resistance to automated training need not be significant if the introduction and demonstration are made in a series of prudent, controlled steps. Such an experimental study might be approached in the following:

1. Undertake an analysis of the efficiency and expense of current training procedures in order to compare them with programed job training.
2. Choose a finite area of job training providing a satisfactory number of experimental trials.
3. Divide the trainees into control and experimental groups (and perhaps, in addition, a "blind" group which is not told of its place in the experimental context) of similar composition. Assessment of trainees should be maximally detailed for purposes of accuracy in evaluation. Predictor or control variables should be isolated and measured prior to the training schedules for use in covariance adjustments. (Suggested data-gathering tools might include: IQ estimates based on the Otis Employment Test—especially Test 2, form B—or the Wechsler Adult Intelligence Scale; scores on the Ohio State University Reading Comprehension Examinations; Bennett's Test of Mechanical Comprehension; Pace's High School Characteristic Index; Stern's Activities Index; subject matter aptitude indices such as the Air Force Electronics Aptitude Index; and specific examination results on pre-knowledge of the course material. For this latter, one might use selected items from course tests. With this battery it should be possible to test for and weigh such factors as latent learning and sensory preconditioning.) Naturally, no single experiment need employ more than a few such instruments; the listing merely indicates the range of the armamentarium.
4. At first, experimentation should be limited to the simplest forms of display device or programed text.
5. Criteria variables, to be studied at completion by all groups of the programed material, would be: time (number of hours of

work on program or in conventional study to completion); test of factual knowledge (items based on objectives of course); test of conceptual facility (use of course concepts in varying problem-contexts); costs (of program preparation and devices, amortized, as against teacher time and student time, monitoring personnel, classroom space, etc.); student reaction (positive or negative attitude expression toward programed teaching as opposed to conventional or previously experienced training, willingness to continue with program as measured at various intervals before completion, interest in further such study as assessed after completion, to be measured through interviews or questionnaire-polling.)

In summary, if programed training is introduced flexibly, in measured steps, with convincing demonstration of its merits at each stage, the new technique can gain authority and acceptance. Large sums of money are involved: the client company and the programing groups as well can only proceed with certainty if the proper base is built for the innovation. A possible cause of delay in use of programing, and the factor that can contaminate its reputation, is the situation described by Levine and Silvern in a recent paper: "...fantastic claims, marketeers, a sudden outbreak of 'consultants', gimmicks and gadgetry without experimental evidence in support of claims, and finally, a rash of untried curricula."

If, on the other hand, cautious pilot projects multiply, industry, which is already eager to learn about the new teaching technology, will develop both sophistication and enthusiasm. Sales are predictable thereafter.

A NEW INDUSTRY RISES

The complex training needs of industry, scarcely less than the educational requirements of the school system, offer vast fields for the effective development and introduction of programed learning. However, it is likely that the behavioral expertise necessary for creating good instructional programs and optimal learning design is not yet fully recognized in either industrial or academic areas. Some industrial companies and public school systems have begun highly preliminary experiments in development of their own programed courses; but it soon becomes clear that effective programed learning requires a greater concentration and integration of specialized scientific ability than achool systems can afford or industries can normally find economical.

In view of these facts, new companies specializing in the development of programed learning have been increasingly emergent within the past year. Moreover, some of these companies also are beginning to serve as academic and industrial consultants in overall learning design. Thus, programs in a growing range and variety of academic fields are now in publication or preparation from several sources—and, expectably enough, at several levels of size, quality, pedagogical depth, and subject-matter coverage. Industrial programs supplied by professional companies can be expected to keep pace in development with academic ones.

To be truly effective, the programing company requires large capitalization; a staff of experts not only in behavioral psychology but also in as wide a range and variety of subject matters as can be afforded; expert analysts of industrial training situations—authorities capable of detailed job and task analysis, examination of the total industrial organization, and redesign of the learning-work situation in whole or in part. Such a company must also have access to academic consultants at all relevant levels and the highest attainable degrees of quality.

The evident complexity, care, and expertise required for reliable high-quality programing and learning design will, in all probability, gradually discourage most industries and schools from attempting to appropriate the preparation of programed instruction to themselves. Thus companies specializing in programed training and behavioral learning research and technique not only may be expected to play an important role in the very near future, but also may well rise to a dominant position as consultants and creators of educational materials generally.

Systems of educational design are most efficiently constructed on an empirical basis, employing tested principles of behavior control, rather than "cookbook" procedures. A number of models for alternative systems exist, from programed manuals and simpler man-machine symbioses to multidimensional looped structures involving computer mediation.

An approach flexible enough to achieve effectiveness under varying conditions demands a constellation of systems factors functioning as an integrated facility. Given a sufficiently broad spectrum of means, a major transformation of present training and education, yielding unprecedented advantages, becomes feasible.

The following are the four indispensable and distinct elements in such a system:

a. Programing and behavioral technology. Here, the central requirement is for scientific expertise, both methodological and substantive, together with access to major research centers.

b. Publication and dissemination. Here, major needs are for size, in the sense of a broad marketing range; soundly structured relationships with schools and local governments; fluency and experience in consumer merchandising; technical efficiency in the manufacture of learning materials.

c. Instrumentation and hardware. In this area, the needs include production and design capacity for a large family of devices ranging from display mechanisms and sound equipment to simulators, closed-loop psychomotor units, and still more specialized instrumentation. Complete familiarity with electronics systems and computer potentials is necessary.

d. Special situation sales and marketing. The required characteristics in this case are a high level of competence in interaction with business, industry, the military, and nonmilitary governmental agencies; access to decision-making levels of management and command; a fluent and articulate sales approach fully utilizing relevant technical information; and the capacity to anticipate emerging markets and potential users.

The normal activity of each member component can predictably derive significant advantage from an interlocking structure of this kind. Additionally, new tasks and new opportunities can be generated through a systems approach to the total educational and training market.

STAGES IN A SYSTEMS APPROACH TO A LEARNING ENVIRONMENT

An optimal approach to creating the learning environment involves first the calibration of goal gradients. In other words, establishing job performance criteria. These performance standards dictate the design of the training process and are established by analysis. Determination of goals and subgoals can usually be achieved on an empirical basis, through available work information; the job or task analysis which grows out of such performance criteria may also modify them. For example, this may mean that in some cases, a set of clearly written job instructions can reduce the place of training. The performance standards are subsequently deepened into a full task analysis by the joint efforts of technical experts and behavioral psychologists. From this task analysis, curriculum specialists and learning methodologists are able to construct the course outline, or syllabus. After identification of student characteristics, such as aptitude level, and determination of the degree of generalization required, flow charts, including lesson-plans, can be developed on a realistic basis. This last step is necessary so that a mosaic of functions can be rationally arranged for maximum response differentiation, thus avoiding intervening variables. This is clearly seen in the case where successive approximations leading to the desired terminal behavior are considered as simple analogues, and the optimal teaching strategy differs from the anticipated course outline. On this basis, a program is constructed; reviewed, tested, rewritten, tested, revised, repeatedly until all validating criteria, in turn are derived from the initial job performance standards, are satisfied.

Presentation characteristics of programs may vary considerably. The simplest case might involve the use of programed texts only, or certain general-purpose display devices handling standard-form materials. At this level, instrumentation is purely auxiliary but may be desirable for reasons of economy, employee morale, or through a need for performance records. More highly specialized display devices, auto-paced, with audio and/or visual components, may be necessary where these differentiations are integral to the training objective. One example involves the training of sonar operators to discriminate between signals and random noise and between different types of signal, achieving a more sensitive interpretation than is possible through reading the visual stimuli, on a screen, into which the initially received sounds have been translated. For this purpose, sound-discrimination training might employ not only aural stimuli but also their visible forms, as on an oscilloscope. Still more complex teaching machines will be necessary in the case of optimal sequence training, where manipulative operations such as maintenance skills require instruction in calibration, inspection, adjustment, repair and replacement as part of a spectrum of trouble-shooting strategies. The learning environment in such cases must simulate in detail the eventual operational environment, reducing behavioral oscillation to a minimum, since "downtime" with major capital equipment and continuous processes is enormously expensive. In still another range of cases, machines might supervise as well as teach, where errors are costly and the cost of quality-control supervision is high. Still other tasks will call for closed-loop psychomotor devices which might, for example, pace the student by adjusting speed to test the maximum capability of the learner. Any one or more of the above devices may be computer mediated, where factors such as multiple-input or high-speed evaluation are desired. As current limits in machine versatility are exceeded, further generations of devices will become possible. It should be noted that this entire technology is learner-centered, in contrast to instructional methods which, lacking active student participation, are organized for maximum teacher convenience.

Variant Learning Environments

Research and practical experience will suggest still wider applications for learning technology. Viewing sales situations as teaching transactions, for example, has suggested the use of psychological knowledge about verbal behavior in sales training.

Sales personnel trained in the control of an interview through its communication variables will be able to maximize the advantages available in these brief interactions. Knowledge gained in these areas, and in the related field of simulation, may evolve an ulterior usefulness so that even such general topics as marketing become susceptible to psychological analysis, permitting the consumer to be treated as a student whose behavior can be predictably shaped.

The Range of Services

The existence of such a complex, and its use of a systems approach, permits the solution of training problems of any magnitude. Along the spectrum, these might vary from such tasks as discriminating the threads of a screw, or color coding transistors, to the informed survey of factors affecting management decisions; from teaching the ability to read technical language or engineering drawings and translating them into job action by means of a programed manual to designing a total training system for a given industry. A total training program must be structured in modular units covering every aspect of training. For example, an industrial chemical company might want all its employees to know more about the basic science underlying the industry or some special chemical field such as polyester resins. Using express stops, branching and segmentation, the same program could be used at every level of the job hierarchy and could be combined in whole or in part with courses in other subjects to fit individual needs. The company would be able to control precisely the degree of training given each individual. It could limit the training or remove all limitations to progress to higher levels. A total system of this kind, utilizing the fullest resources of the service complex, would involve continuous supply to the client of all needed training, at levels of employment from wage-roll workers to upper executives. Here, the systems approach means that job training is planned contemporaneously with changes in production technology.

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The Industrial Market for Programed Instruction

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This year, industry will spend roughly $1,000,000,000 to train some 800,000 employees. If programed instruction continues to achieve the approximately one-third reduction in training time that initial installations have indicated, the technique might account for a large portion of this vast market for training materials. Because the industrial-training market is three times as great as the combined school and college textbook market, many companies active in programed instruction have announced their intention to participate in the industrial market.

Interest in programed materials is not confined to companies selling such materials. Training directors across the country have commented favorably on the new medium, and some 20 to 30 large corporations have already purchased programs and/or machines. The American Society of Training Directors (ASTD) is actively promoting programed instruction; a year and a half ago its monthly journal began a continuing series of articles on the subject, and ASTD has devoted many hours of its recent conventions to discussions of programed instruction.

Thus, although interest in programed instruction is widespread among potential industrial buyers and potential suppliers, there is a paucity of published material regarding the nature of the market. This article represents one set of opinions regarding the factors that bear on the marketing of programed materials to industry.

FACTORS FAVORING INDUSTRIAL ACCEPTANCE OF PROGRAMED INSTRUCTION

Perhaps the most important single factor favoring rapid industrial acceptance of programed instruction is cost-plus-fixed-fee (CPFF) contracting for government, particularly the military. In many of these contracts, speed of production and quality of workmanship are rightly more important than precise cost to the government. By including the cost of programed instruction in their bids, manufacturers can experiment with this technique at no cost to themselves and, at the same time, achieve significant savings in time and improvements in quality of product. Furthermore, assuming that workers' speed and effectiveness are increased, the company, in effect, will have increased the productive capacity of its facilities. This increase in capacity will not affect margins on individual CPFF contracts, but it might permit the company to accept more contracts than otherwise would be possible. If so, total profits and return on investment will increase; if not, the company will lose nothing because the government bears the cost of the experiment.

Defense contractors are not the only companies that have good reason to use programed instruction. Many companies experience a strongly seasonal pattern of sales and employment; retailing operations peak in the pre-Christmas season, and other companies have definite peaks and dips at various times of the year. Because of these variations such companies repeatedly must train new personnel to perform specific skilled tasks for relatively short periods of time. By the time the new employees become skilled, the seasonal peak ends. It is impossible to estimate the total dollar cost of training seasonal employees, but some companies report that the expense is as much as one-third or even one-half the total compensation paid the temporary employee during the seasonal peak. Such companies will be favorably disposed toward any training technique that promises to reduce training time.

Programed instruction also will be useful to companies whose business does not fluctuate markedly from season to season but that typically experience a high rate of product or personnel turnover. High turnover is characteristic of airline stewardesses, insurance and mutual fund salesmen, and some key employees in other service industries. Although employee turnover in many space age industries is low, their product lines are so highly technical and subject to such rapid change that production workers and salesmen must be retrained repeatedly. The pharmaceutical, semiconductor, and office-machine fields are three prime examples of industries that require frequent retraining of personnel because products change so often.

Customer training is related to the training of company personnel to handle rapidly changing product lines. As American industry produces increasingly sophisticated equipment, more and more emphasis is being placed on training users to gain maximum benefit from the devices. In electronic data processing, for example, IBM and other companies have established training centers for customer personnel. A similar situation is reportedly developing in electronic and ultrasonic test equipment and certain types of machine tools. As data processing, information retrieval, tape-controlled production equipment, and other young science-based industries undergo further development, customer training should become an even more important sales tool than it is now.

Many students of the business-machine industry already insist that IBM's extraordinary growth rate is due, not to the superiority of its equipment, but rather to the company's ability to help customers make the most effective use of data-processing systems.

Programed instruction could be used to train customers, not only to use equipment, but also to maintain it. As the tools of industry become more advanced in design, they require increasingly sophisticated and specialized maintenance personnel. Even in those cases where the selling or leasing company enters into a maintenance contract with the customer, someone must be trained to do the work. The importance of training in trouble shooting is not confined to complex industrial equipment. Television-receiver, washing-machine, and refrigerator repairmen already undergo highly technical training, and, if color or pay television and ultrasonic-cooking ranges become commonplace, a whole new complex of service problems will materialize. Programed instruction is one of the major possibilities for coping with these heightened demands on the skills of repair technicians.

In addition to job-related training programs, many of our more progressive companies have begun to offer to their employees courses of more general value. For example, Polaroid employees can study basic courses in Spelling and English Grammar. In the near future, Polaroid management hopes to offer to its employees classes in various foreign languages. Other firms have similar plans to help workers expand their educational backgrounds. On a slightly more commercial level, most major firms offer management-development programs featuring such courses as industrial relations, economics, marketing, and corporate finance. If programed instruction can provide an efficient means of presenting either general or management-development subjects, it will undoubtedly be well received by industry.

Cost-plus-fixed-fee contracts, seasonal business fluctuations, high rates of product and personnel turnover, customer training in the operation and maintenance of equipment, and employee-education programs are major factors that will convince industry to adopt programed instruction. But, there are two other situations that also might help industrial-programing organizations to sell their products. The efforts of the National Association for the Advancement of Colored People (NAACP) to secure positions for Negro workers is one situation, and the activities of various area-development councils is the other. The NAACP has effectively employed economic boycotts to convince various industrial organizations to hire Negros, but has found it difficult to obtain high paying positions for these people. One reason for this difficulty is the Negro's characteristic lack of specialized training in skilled functions. Programed instruction might be a relatively inexpensive and rapid solution to the problem. Similarly, many states and counties, particularly in the South, have convinced businesses to relocate to their areas by offering generous plant financing and tax shields. In some cases, however, these area-development councils have failed to attract industry because their regions lack personnel trained in the advanced skills required by atomic-age companies. Again, programed instruction might be the answer.

PROBLEMS IN SECURING INDUSTRIAL ACCEPTANCE OF PROGRAMED INSTRUCTION

Industry clearly needs to improve its training procedures, but it probably will not accept programed instruction on a large scale until several problems have been solved. Perhaps the most critical of these problems is the disparity of backgrounds among individuals to be trained in a given subject. Unlike schools, where one fifth grader has much the same background for each course as does every other fifth grader, there is usually no common background among the employees a company assigns to a specific task. For example, the roster of a drug company's salesmen might include some men who have attended medical school, others with no graduate training but an undergraduate background in science, and several with only liberal arts training. Yet, if programed instruction is to be effective, it must be suited to the previous experience of the trainee.

If too many frames of the program are explanations of technical terms that many students already understand, students will find the program boring as well as too time consuming. But, if the program does not explain these terms, it might frustrate those trainees who are relatively unfamiliar with the material. The extent to which employee backgrounds differ will vary from company to company and from subject to subject, but it does seem clear that background disparity among trainees will be a significant obstacle to industrial programers. The solution of the difficulty will probably hinge on the flexibility with which the material is presented. Branching (use of remedial frames), skipping (letting experienced trainees omit parts of the material), tracking (preparation of separate programs for trainees with different backgrounds), or some combination of these three might be necessary. Such refinements will increase the time and the expense involved in program development.

Programing is a lengthy and expensive process even without such refinements as branching, skipping, and tracking. An industrial programer probably will not be able to prepare more than three or four frames per hour. If so, and if a programer's total compensation, including fringe benefits, averages $3.50 per hour, the direct cost of industrial programing will be about 90 cents to $1.20 per frame.

Because a typical industrial program might run to 2,500-5,000 frames (the equivalent of a 50-100 page, conventionally written manual), the direct cost of writing the program would range from $2,500 to $3,000 for the shorter programs and from $4,500 to $6,000 for the longer programs. Allowing for 75% overhead, development costs would total $3,950 to $5,250 for 2,500 frames and $7,900 to $10,500 for 5,000 frames. Testing and rewriting could increase these values by 25-50%, and if an outside contractor performs the work, further allowance must be made for that company's profit margin. Finally, reproduction costs must be considered, although these will vary markedly with the presentation format and the number of copies required.

On balance, programs produced by a company for its own use might cost $5.00 to $7.50 per frame, whereas those prepared by an outside company might run to $10.00 or more per frame. If the programs are used in conjunction with teaching machines, the initial cost might be significantly higher.

Thus, the cost of even a 2,500-frame program will be in the tens of thousands of dollars. As a result, high-level-management approval probably will be necessary for purchases of industrial programs prepared on a contract basis, and decisions, in most cases, will be based on strictly economic considerations.* Only where programed instruction offers sufficiently tangible savings to justify the investment will they be accepted.

Unfortunately, it is difficult to isolate costs and savings in the industrial-training situation. The author has read industrial proposals that devote several pages to the development of "dollar value of savings to be achieved via programed instruction" or some similarly labeled sum of staggering proportions. But analysis of the projected savings usually reveals certain invalid or at least questionable assumptions.

The most common assumption is that programed instruction somehow will reduce overhead expenses. If the company normally spends for overhead a sum equal to direct-labor cost, the writers of industrial proposals often assume that a reduction in direct-labor hours will result in a proportionate saving in overhead. In actual practice, this usually will not be the case. Most components of overhead will remain relatively constant regardless of any reductions in training time achieved by programed instruction.

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*Customer training and CPFF contracts are the major exceptions to this statement.

Similar to the overhead "trap", but more subtle, is the difficulty of computing the value of the man-hours saved through programed instruction. It is relatively simple to compute the number of man-hours saved, but in many cases nothing is gained by saving the time. For example, if the foreman now spends several hours a day training apprentices to operate a certain type of machinery, eliminating this function from his duties will be valuable only if the time he saves can be put to productive use. In many situations, the foreman would be idle for part of the day if he were not training new workers. Management, therefore, should carefully determine whether or not the time saved by programed instruction will actually improve the annual statement.

Once management is convinced that worthwhile savings might be achieved with programed instruction, it should next decide whether or not the anticipated savings justify the purchase. Management should decide upon an acceptable relationship between investment and savings. Considering the difficulty of achieving the time saving and measuring its value to the company, management probably will demand high rates of return on investments in programed instruction. For this reason the author doubts that industry will accept programing proposals that anticipate more than a one- or two-year payback.

Just as management probably will prove reluctant to accept bids promising long paybacks, it will, in many cases, turn down programing proposals because of the long lead time involved. To use the same numbers as in the section on the cost of the technique, let us assume that a programer can create three or four frames per hour and that an industrial program ranges between 2,500 and 5,000 frames. With these assumptions, we find that 600-800 man-hours are required for the shorter program and 1,250-1,700 for the longer one. If a single programer were to work on a 2,500-frame program, it would take him roughly fifteen 40-hr weeks. Writing a 5,000-frame program might take over six man-months. These are long time periods, and in many cases, management will be unable to wait while the program is undergoing development.

COMPETITION FROM OTHER MEDIA

A general difficulty that will be encountered by companies attempting to sell programed instruction to industry is competition from other recently developed training techniques.* For example,

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*Any of these materials could be used in conjunction with programed instruction, but budgetary considerations make it unlikely that this will be the case.

Technical Animations, Inc. of Port Washington, New York has developed an ingenious method of demonstrating various processes. The method known as "Technamation", involves plastic transparencies that are animated either mechanically or by use of rotary polarization. A number of leading manufacturing organizations, including Brunswick Balke, General Electric, American Machine and Foundry, and Bulova Watch have reportedly used Technamation successfully in a variety of applications.

Other sources of competition will be various concerns engaged in the production of life-sized simulators. Burtek and Link Aviation are but two of the leading companies active in this field. All of their training aids compete in one manner or another with programed instruction.

The final and most direct source of competition will be conventional technical writing companies. The present dollar volume for technical manuals is several hundred million dollars, but most of the individual companies involved are rather small in size, or are minor divisions of large companies. Miles Samuelson, Lytle, Genge, Howard W. Sams, and the Technical-Writing-Service division of McGraw-Hill are all active. But, no one firm sells as much as $5,000,000 per year of technical manuals.

HOW WILL THE INDUSTRIAL MARKET DEVELOP?

As noted above, most of the technical writing companies are rather small in size. Technical Animations, Burtek, Link, and other firms offering training hardware are also modest-sized operations. The author believes that the same conditions that have led to the present profusion of small industrial training firms will tend to fragment the industrial market for programed instruction.

Several factors are responsible for the present situation. First is the tendency of big companies to develop their own training departments. The existence of large staffs of qualified personnel means that most major companies are capable of producing their own training materials and devices internally. Industrial firms in this position tend to subcontract only those materials that are needed on such a large scale or that require such specialized creative or production facilities that it would be uneconomical for the using company to produce them itself. In other words, there is a built-in limitation on the dollar volume that producers of training aids can sell to a given company. Once this limit, which varies from company to company, has been reached, the user probably will perform the work and no longer contract with another company for the work.

There already are indications that many companies with large annual training costs are developing their own internal programing capabilities. One informed source reports that there are no fewer than 27 independent programing efforts underway at IBM. Judging by the volume of inquiries received by the Center for Programed Instruction and other nonprofit groups, many training directors are anxious to develop programing staffs. As knowledge of programing techniques becomes more widely disseminated, it seems likely that the trend toward internal program development will continue.

Even if the major potential customers of industrial programing organizations do not develop their own capability in this area, the growth of such programing companies is likely to be severely limited by geographical considerations. Most industrial programs will require close coordination between the programer and the industrial organization because the material is, in many cases, highly technical, and the programer will rarely be a subject-matter expert. He must work closely with the using concern, therefore, to ensure that he is actually presenting the desired material. To have frequent discussions with clients, the programing organization must either maintain an office in each geographic locale in which it hopes to secure contracts or allow in its contract price for the travel expenses of the men in the field.

In the opinion of the writer, there is only one way that an industrial programing company can achieve significant nation-wide volume and a proprietary position. This is by preparing programs covering material that must be learned by employees of many companies, but in which the volume sold to each company would not justify that firm's establishing an "in-house" programing capability. Programs of this sort would include those dealing with the use of various measuring devices, such as micrometers and calculating machines, and basic industrial subjects, such as industrial relations, economics, basic electronics, mathematics, antitrust regulations, and a variety of other topics that recur throughout industry.

There are other, more specialized, types of material that have widespread applicability. These programs mainly cover certain clerical activities common to many companies within a given industry. For example, Learn-A-Max Corp. of Indianapolis has secured one contract to prepare a program for training bank clerks and another for retail-sales clerks. Learn-A-Max was able to offer an economical bid price by retaining rights to sell the programs to other banks and retailing organizations that, because of their geographic location, do not compete with the companies that let the initial contracts. Assuming that the programs prove effective, Learn-A-Max might well achieve a six- or seven-figure sales volume for each program. Furthermore, the nature of the subjects probably will not change markedly over the years, and

Learn-A-Max might have developed the nucleus of a repeat business similar to that of book publishers with lists of back titles.

Other programing companies should find it possible to use the Learn-A-Max strategy to advantage in many areas. U. S. Industries has secured a contract to develop a program for training salesmen at Prudential Life Insurance Company, and Hughes Aircraft has one for training firemen. Similar subjects that come readily to mind include programs for training mutual-fund salesmen and jet airline pilots to pass qualifying examinations.

Programs that have proved successful in presenting widely needed subjects should be a continuing source of income to the programed-instruction company. Once a program has produced satisfactory results for several different companies, it will be extremely difficult for a new, competing program to gain a significant share of the market because no potential buyer is likely to purchase a new and untested program when a demonstrably successful one is available. This built-in market resistance, the investment required to prepare a competing program, and the risk that it might prove to be no more efficient, or even less efficient, than the one already on the market and hence unsaleable, should tend to discourage new firms from competing with established programs.

Some Economic Realities of Teaching-Machine Instruction

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The current level of interest in auto-instructional techniques emphasizes a growing concern that traditional methods of instruction might not be capable of implementing the expanding need for more effective education and technical training. This interest has led to important strides in the techniques of auto-instruction, its breadth of application, and the design of accompanying devices. Systematic research already completed has, at least partially, verified the potentialities of programed instruction and has lent support to plans for the eventual wide-scale adoption of teaching machines in the classroom and in vocational training programs.

It has been only recently, however, that it has been possible to consider certain of the problems made apparent through extensive field studies employing auto-instructional materials. During the spring of 1960, an investigation of the use of auto-instructional materials in an education situation was conducted by the authors under the sponsorship of the United States Office of Education. This was the first field study of auto-instruction carried out on a large enough scale to require a detailed consideration of cost factors involved in the use of these materials. Up to that time, only small amounts of auto-instructional materials were available, no published programs had been offered for sale, and only prototype models of devices had been produced.

During the course of this study, some 500 students were furnished with auto-instructional materials consisting of about 3,000 frames in high-school physics. These materials represented slightly less than 20% of the content of the corresponding physics course but, nevertheless, involved logistics of considerable magnitude. For instance, the materials furnished to these 500 students required over 3 1/2 tons of paper and 120 dozen loose-leaf notebooks. Had the entire course been prepared in the programed-text format used, it would have been necessary to furnish each student with the equivalent of twenty two 300-page volumes at an estimated cost of $66 per student.

These estimates make it apparent that efforts to implement auto-instructional research would likely be stymied until the cost of auto-instruction could be reduced to satisfactory levels. As will be described shortly, an expenditure of the public schools of more than $5 per student per course per year would be prohibitive at the present time. Even in industrial training, where the allowances made for training costs are considerably higher, large expenditures for course materials are certain to be met with considerable resistance. Apprehensive that the bulk of programed materials being prepared might fail to meet the needs of education and training in spite of their technical advantages, we decided that a detailed analysis of costs was needed to clarify the problems involved.

In investigating cost factors in auto-instruction, two principal sources of expense need to be considered: first, the cost of writing or developing a typical program; and, second, the cost of reproducing it for classroom or on-the-job training. Certain applications of these materials might necessitate additional expenses. These applications include programs involving a high degree of flexibility or those involving skill learning that could be less expensively achieved through the use of a human tutor. To simplify the analysis, however, only those programs that warrant general distribution were considered. Furthermore, because of the rather extensive differences in technique involved in preparing short-frame, constructed-response programs (cf. Skinner) as opposed to paragraph-length, multiple-choice "intrinsic" programs (cf. Crowder), the costs involved in each of these two approaches are apt to be substantially different. In this analysis, only the constructed-response type of program is considered.

THE COST OF PREPARING THE PROGRAM

To determine the cost of preparing a typical program, certain assumptions had to be made. These assumptions are based on experience obtained during the preparation of the physics materials. First, it is necessary to assume that the personnel responsible for preparing the program already have been fully trained. It was discovered during the 1960 study that those reasonably skilled in psychology, education, and the subject matter being programed often required several months to reach satisfactory levels of proficiency in preparing frames.

Second, it is assumed that the developmental procedure involved in preparing the program includes all the steps that apparently contribute to the production of successful auto-instructional materials. These steps include a reasonable amount of editorial review, repeated tryouts with individual subjects, diligent efforts to revise the program on the basis of student responses, and extensive assistance from a subject-matter expert.

Third, it is assumed that the program being prepared is not unusually difficult or easy to write. The preparation of materials in foreign-language vocabularies or arithmetic, for example, do not involve nearly as much effort per frame as materials that instruct students in principles and applications. On the other hand, it is not assumed that as much time would be spent per frame as would be required to program materials such as might be involved in problem solving or creative writing. In these subjects, the subject matter is such that considerable preliminary effort is required to determine exactly what skills are to be taught and to sequence the teaching of these skills in an optimum fashion.

Fourth, it is assumed that the program is being prepared on a production rather than a research basis. It became apparent during the development of the physics materials that a minimum goal for programed materials is that they do produce the desired level of achievement with a minimum number of student errors. In many cases, research programs have the additional aim of producing achievement as efficiently as possible and as consistent with a given theoretical position as possible. These latter programs require greater effort to prepare, and, although they generally can be expected to contribute to an understanding of programing, the additional effort will not generally yield proportionate increases in learning efficiency.

Fifth, it also is assumed that the program will be of sufficient quality to demonstrate the effectiveness of the auto-instructional approach and, thus, find acceptance in public-school education or in industrial or technical training.

As a basis for estimating developmental costs, the most suitable standard seemed to us to be the cost per frame. An accurate estimate of the number of frames that might be required to program a typical course is difficult to make, however. Not only does the estimate depend heavily on the subject matter and the ability level of students or trainees for whom the program is intended, but it also is influenced by the current repertoire of the students, by the degree of retention or proficiency aimed for, and by the complementary use of other instructional methods. As an example, retention probably is closely related to the number of times a given response has been practiced in the program. The greater retention desired, the greater the number of frames needed in the program.

On the basis of the physics study, a year-long physics course would require approximately 15,000 frames. This estimate of roughly 100 frames per instructional hour has been substantiated in the preparation of other programs at American Institute for Research. Although it might be possible to prepare a program in high-school physics that consisted of as few as 7,000 or 8,000 frames, there probably is little to be gained by skimping on the amount of material covered, the amount of review provided, and the number of examples used. The figure of 100 frames per instructional hour has been found to be equally applicable in industrial and military training. Thus, a technical training course of about six weeks in duration might involve about 24,000 frames.

The amount of time required to write a single frame was estimated by means of a survey of a number of programer including Glaser, Evans, Homme, Holland, and Eigen. From their replies, it was possible to estimate a typical production rate of between one and two frames per hour. This does not represent the amount of time necessary to draft a frame but, rather, the composite time needed to draft, edit, tryout, and revise frames so that they are ready for field tryout.* On the basis of these figures, the preparation of a 15,000-frame program would require approximately 10,000 man-hours, or five man-years in professional salaries alone. If reasonable allowances are then made for researching the subject matter, secretarial and administrative support, overhead, paying test subjects, and limited duplication of the program, the overall cost could well amount to $75,000, or $5 per frame.

In practice, we have found that even an estimate of this magnitude might be low, depending on the difficulties encountered. The most difficult step in preparing a program, like many other endeavors, is in getting started. Thus, a relatively short program, or one that requires the development of frames that cannot be modeled after previous work, requires a substantially greater amount of time per frame so that the cost of preparing a 400 or 500 frame program might well be as much as $5,000. It should be pointed out, however, that costs of this magnitude cannot be considered excessive, especially when amortized over several years and many thousands of students. If developmental costs of $75,000, for example, are prorated over a conservative estimate of 30,000 students per year for five years, the basic cost for the entire program is only 50 cents per student. This is a sound argument for not skimping on frames or on the amount of tryout and revision.

It should be recognized that auto-instructional programing is not likely to remain an exclusive art for very long. Teachers, writers, and technical experts will soon be preparing programed materials as they prepare textbooks today: on their own time and with a minimum of expense. While a trend in this direction is economically unavoidable, it should be viewed with caution. The educator working at home, regardless of his skills and good intentions, is rarely in a position to provide the thousands of man-hours necessary to prepare a good course. Tryout of the program alone requires considerable effort. Reviewing even one student's responses to a 15,000-frame program is a 100-hour job at the rate of 2 1/2 frames per minute. Because of the large number of man-hours involved, it is not likely that someone working in his spare time will be in a position to persist long enough to prepare a full-length course properly. Even if one were to prepare only 8,000 frames and, by omitting much of the tryout and review, average four frames per hour, the complete program would still require his *fulltime* efforts for an entire year.

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*This estimate has since been verified by a more extensive survey completed by Joseph W. Rigney and Edward B. Fry of the University of Southern California.

THE COST OF REPRODUCING THE PROGRAM

The second major problem considered in our analysis was the expense involved in reproducing a program for student use. Here too, several variables, such as the size of frame, the use of illustrations, and provision for automatic scoring affect an estimate of costs. It also is important to consider how the program will be used. For example, auto-instructional devices ordinarily cannot be taken home from school or work, but materials prepared in programed-textbook format can be carried about by the student.

Perhaps the simplest form of presentation is that using stacks of cards, programed textbooks, or other formats that require no extrinsic devices. The size of frames reproduced on paper can vary considerably. The programed textbooks prepared for the physics study contained presentation and confirmation panels that were about 2 x 7 in. each or 28 in.^2 for the two portions of a frame. If five panels are placed on a page, a book of about 6,000 pages is required.

It is possible, of course, to reduce the space devoted to each frame, but it seems unlikely that the presentation portion of a frame can be reduced to much less than 6 in.^2 Because the confirmation panel rarely needs to be as large, there is a tendency to double up on panels by placing the confirmation panel next to the following presentation panel. This approach reduces the amount of paper required by more than one-third, but it has the unfortunate disadvantage of potentially contaminating a student's response. Whenever the preceding answer is visible to the student, it cannot meaningfully serve as the response to the frame being attempted. Thus, it again is questionable whether sacrificing some of the effectiveness of the program so as to reduce the cost of production is a real saving.

Returning to the physics study, the materials supplied to the students in the 25 classes involved in the experiment did not require printing on a scale comparable to what would be expected were the program to be distributed for general use. Thus, while estimates of the costs of reproducing a full-length high-school program, based on our experience, run to more than $60 per student, the printing of a larger number of copies would yield a considerably lower figure. For instance, if it is assumed that printing methods similar to those employed in reproducing college workbooks or paper-bound editions of classics are used, 15,000 frames might be provided in programed textbook form for as little as $10 or $12 per copy.*

It has been suggested that substantial economies can be realized if the materials are prepared in such a way that they are reuseable. It then would be possible to amortize the cost of the program over several students as textbooks are today. Techniques for insuring the reuseability of programed materials have not shown much promise, however. One possible solution is to have the student make only covert responses rather than having them make overt responses that are written into the book. Whether or not covert responding is as satisfactory as overt responding has not been thoroughly investigated. Until it has been satisfactorily demonstrated that covert responding is as effective as overt responding, however, it is likely that written responses will still be preferable. Another solution that frequently has been suggested is to provide the student with an auxiliary answer book for recording his responses. As noted earlier, any format that leaves previous answers exposed encourages the use of inappropriate cues for responding and should be avoided. Thus, any answer record book would have to be designed in such a way as to cover previous responses.

Temporarily setting aside further consideration of programed textbooks, it is possible that relatively simple devices can be used that present the program on paper disks, paper tape, or sheets of paper. A variety of such devices are already available at a cost of between $3 and $35. Except for those devices that facilitate the reuse of a program, the fact that these mechanical methods of presentation depend on printed material makes it clear that substantial economies will rarely result, and teaching machines of this type cannot be expected to reduce the cost of programed instruction materially. Furthermore, when one considers the cost of the device itself, the expense per student is increased

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*The programed text, *English 2600,* written by Joseph C. Blumenthal and published by Harcourt, Brace and Co., contains 2,600 frames of the constructed-response type. It sells for $2.60. The program by Holland and Skinner, *The Analysis of Behavior,* published by McGraw-Hill Book Co. contains somewhat fewer frames. It retails at $5.95 for the cloth bound edition, less in paperback.

It has been estimated that, with such devices and assuming that the mechanism includes an answer tape on which the student can record his answers, it would be necessary to furnish a class or group with only one-tenth as many programs as there were students. On the other hand, the preparation of such a limited amount of materials will increase the cost on a per-copy basis. In addition, it currently is not possible to reproduce paper tapes by any reasonable printing process; tapes must be printed in sheet form and then glued together. While inexpensive devices of this sort potentially will find acceptance, it is not likely that the combined cost of the materials and the devices could be reduced below $3 or $4 per student per course per year.

Turning to a third possibility, the use of microfilm, we find that devices are again required and that these devices can range from a simple 16 mm filmstrip projector to highly complex apparatus such as the Wyckoff Film-Tutor. These complex devices are priced as high as several hundred dollars each, but simpler film devices could probably be constructed to sell for considerably under $25 and be useable for about five years at the rate of five uses per day.

Film can be relatively inexpensive when compared with printed pages. Once the original is prepared, copies can be made inexpensively. For example, 15,000 frames can be reproduced on less than 400 ft of 16 mm film for under $5. This cost almost invariably would be less than half that involved in preparing a printed, programed textbook that includes the same amount of material. Furthermore, film generally is more easily stored and considerably more durable than printed materials. Basically, it also is less expensive to prepare. If it could be assumed that each film strip would be used for a period of five years, and that it could be used by two students concurrently, the net cost would be only 50 cents per student per course per year—far less than the cost of presentation by means of programed textbook, or the simple devices previously described.

For many purposes then, it is likely that the presentation of auto-instructional materials on film might be the most economical procedure. The widespread use of film will depend, however, on the availability of a less expensive device than is now obtainable. A device costing only $12.50 still represents an expenditure of 50 cents per student per course even when it is assumed that the device will be used five times a day and will not require replacement for five years. Although such devices are not currently available, it seems clear that they could be produced commercially if the market were large enough.

On the basis of a projector that costs perhaps $25, or $1 per student per course, plus a cost of 50 cents per student for the use of the filmed program, it is possible to estimate that auto-instructional materials presented by means of film would be relatively inexpensive. Of course, to this cost must be added the estimate of 50 cents per student for the development of the program. But even then, it is quite conceivable that auto-instructional programs can be utilized for no more than $2 per student per course per year when the program has been reproduced on film. Only when the volume of sales reached very large numbers would it be feasible to duplicate these low costs in book format. If an estimate is made on the basis of inexpensive, large-volume, pocket-book editions, it is quite possible that 15,000 frames could be reproduced for about $4. If multiple uses of each copy is assumed, and some solution to the problem of recording answers is achieved, the cost per student could be as low as $1.50 for each course. Both this estimate and the one indicated for microfilm devices are within the range of magnitude considered acceptable for a high-school textbook, and are less than the cost of many industrial training manuals.

In addition to these immediate considerations with respect to devices, additional economic problems will have to be investigated before full advantage can be taken of auto-instructional techniques in educational, military, or industrial instruction. It has been suggested, for instance, that devices are more desirable than programed textbooks because they might prevent cheating and produce increased motivation. The effects of such device characteristics have not yet been demonstrated, however. A further problem to be considered before devices are purchased is that of the availability of programs prepared so that they fit the device. Until the industry promotes some standardization, it is unlikely that more than a limited number of programs could be used in any one kind of teaching machine.

The introduction of auto-instructional materials into the classroom or industrial training situation also must be considered in terms of the merits of this form of instruction. In spite of the fact that programs might be more expensive than conventional textbooks, it is possible that, dollar for dollar, programed materials produced substantially greater achievement. How much one is willing to pay for learning is a question that cannot be evaluated experimentally. Even if programed instruction were only equal to that offered by the average "live" instructor, there is reason to believe that auto-instruction can provide more economical education and training than can be achieved by current methods. It might be supposed, for example, that the introduction of teaching machines might reduce the need for teachers, at least to a limited extent. With assistance from programed materials, each instructor would be able to supervise and give personal instruction to far greater numbers of students than is possible at the present time.

Suppose, for example, an industrial concern offered a four-week training course that involved 3 hr of instruction each weekday, or a total of 160 instructional hours. For purposes of this analysis, let us assume that the course is offered at a central location requiring the students to live away from home for about 27 days. While he is receiving instruction, the student's morale is apt to reflect his separation from his family, his job productivity is zero, and the student with greater ability must remain in training until the slower students have learned. Without auto-instruction, the industry also must pay instructors, furnish classroom facilities, be generally content with current levels of achievement and with lack of uniform quality from instructor to instructor. Ignoring *all* of these considerations, let us consider only the daily allowance of $15.00 provided by the company to offset the trainees living expenses while at the school. This expense *alone* amounts to approximately $400 per student for the four week course. If that course were to be programed, the 160 instructional hours will represent no more than 16,000 frames. Even taking a high estimate of $10.00 per frame including tryout, the total cost of preparing the program would be only $160,000. It can be seen, then, that the total cost of preparing the program could be amortized over only 400 students on the basis of the cost of per diem alone.

In educational situations, of course, students cost nothing but, in spite of their low salaries, the overall cost of teachers is still considerable. Based on an estimated annual salary of $6,000, a teacher who averages 30 students per class is paid approximately $200 per pupil per year. The programing of a full year of high school would involve the preparations of roughly 75,000 frames. At $5.00 per frame, this would amount to an outlay of $375,000, which seems to be a large sum but which actually represents the average annual expenditure for only 1,875 students—far less than 1% of all students enrolled in any one grade at one time. Even if it is assumed that some teachers still will be required, with assistance from programed materials, each teacher would be able to supervise and give personal attention to far greater numbers of students than is possible at present, at a far smaller overall cost. It is clear then that, compared to the costs of instruction at the present time, the seemingly large outlays required to prepare auto-instructional materials are actually relatively small.

From the cost estimates that have been described, it is possible to draw five conclusions. First, compared with the cost of reproduction, developmental costs are relatively small. Second, an inexpensive microfilm-presenting device is needed, and when it becomes available, programed materials can be provided to students at roughly $2 per course. Third, only when large numbers of copies are involved will it be economical to present auto-instructional materials in programed-textbook form. Fourth, the apparently substantial cost of preparing a program actually is relatively small when compared with the cost of providing instruction by more conventional means. And, fifth, although it is likely that the cost of auto-instructional materials might not be low enough for general use for the next several years, there is every reason to believe that economic considerations will not offer lasting obstacles to the wide-scale adoption of auto-instructional methods for enhancing student achievement.

Programed Learning: An Overview of Personnel and Financial Requirements

By WILLIAM DEUTSCH
Corrigan Communications, Incorporated

Many preliminary research reports have made such statements as "Through programing, we have achieved a 50% increase in the effectiveness of our training procedures." There is reason to believe that such reports at some levels are reasonably accurate, but there are not now available enough original research papers to verify this.

Industrial research is, for the most part, not readily available for public distribution. Industrial concerns currently pursuing research in automated instruction usually reply to requests for information with such generalities as "a 50% reduction in training time," "a perceptible gain in training effectiveness," "a 40% increase in the effectiveness of training." One leading industrial representative answered inquiries with "Our research thus far has not been controlled to the extent that we would want the results reported to .... scientific organizations ...." It is hoped that, by next year, well controlled, thoroughly documented research reports will be released from some of these industrial sources.

Figure 5-5-1 tends to support this prediction for next year's research reports. It serves to emphasize the fact that we are on the verge of an industrial expansion that is undoubtedly related to our population growth.

As can be seen from Fig. 5-5-1, the last three years have been prolific in terms of instructional devices and programing. In 1959, there were only three companies making an industrial effort in the auto-instructional field: Rheem Manufacturing, Western Design, and Corrigan and Associates; in 1960 there was a potential market worthy of the investments of 17 major industrial concerns. The number of companies has continued to grow until, by June, 1960, there were better than 63 major industrial corporations anticipating investments of approximately $1,000,000 each into this new industrial market. At the present rate of growth, it is difficult to estimate what the situation will be in 1962. As one investor stated recently, "Automated instruction represents one of the first new major industries in the last fifty years."

Why has there been this tremendous interest and growth in this

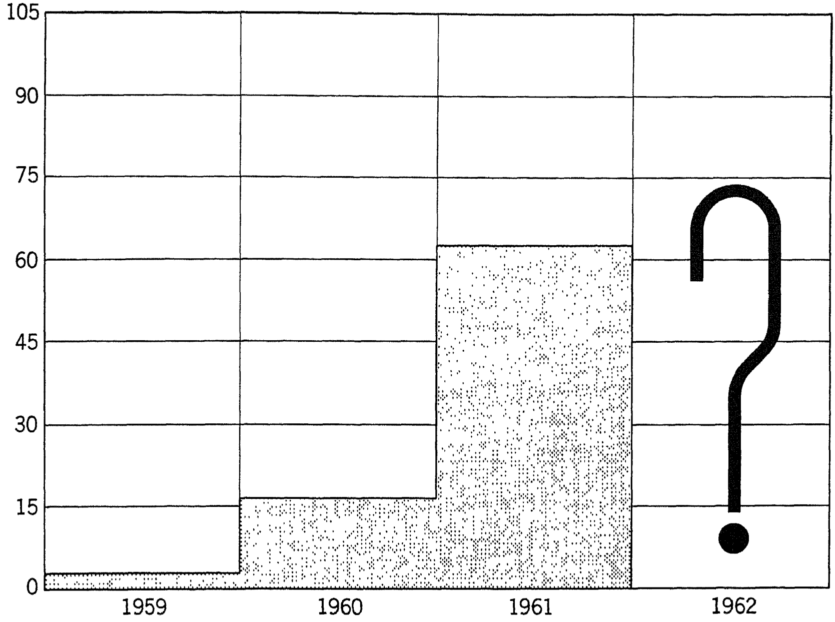

Fig. 5-5-1 Number of major industrial companies active in the auto-instructional field

field in the past three years? Psychologists and educators have been aware of these techniques for decades—at least as long ago as 1920 when Dr. Sidney Pressey started some of his early work. There are two reasons for this rapid growth at this time: first, as mentioned above, the population growth and second, perhaps a less direct cause, the result of the publicity resulting from the initial research sponsored by the three industrial pioneers mentioned earlier and carried out at various universities and colleges throughout the country.

These early experimental projects lent themselves very well to journalistic sensationalism. Such publicity not only left mental images that sometimes were derogatory but, also, created what might be called a "threat-bypass" field. Many parents immediately hurried to educators at colleges and universities and asked such questions as "Will our children be taught by robots?"

These questions stimulated the thinking of educators who consulted with industrial concerns throughout the country to ask whether it was possible to teach with machines. The industrialists, in turn, taking it for granted that it was possible to teach with automated devices, asked their marketing specialists, "Is this a feasible marketing area?" The marketing specialists, finally, tried to view the field from the perspective of financial possibilities.

FACTORS INVOLVED IN CONVERTING TO AUTO-INSTRUCTION

The first important factor in the automated instruction process is the preparation of the program. This involves variables such as the following:

a. The length of the program.
b. The type of programing required.
c. The complexity and organization of the subject matter.
d. The level of training competency desired.
e. The predetermined level of student comprehension.

The type of programing selected will, to a large extent, determine the type of machine that can be used. The degree of difficulty of subject matter has the effects shown in Table 5-5-1.

Table 5-5-1 Programing Conversion Data

Subject-matter level	Length of conventional course (hours)	Length of programed course (hours)	Frames prepared per hour	Preparation time	
				Man-hours	Man-months
Difficult	20	11.66	1.5	699	4.13
	10	5.83	1.5	349	2.07
	5	2.92	1.5	175	1.04
Medium	20	11.66	2.0	525	3.10
	10	5.83	2.0	262	1.55
	5	2.92	2.0	131	0.77
Easy	20	11.66	2.5	420	2.48
	10	5.83	2.5	210	1.24
	5	2.92	2.5	105	0.62

These data are derived from the savings in training time reported for a number of industrial experimental research projects. The savings varied from 33% to about 50% over conventional training courses. The average was about 41%. Thus, we can see that a conventional training course with material of medium difficulty requiring 10 hr of training time would require only about 5.83 hr of programed or auto-instructional training—a saving in training time of approximately 41%.

The number of frames prepared per hour represents the average number of frames we can expect an experienced programer to write in an hour. The sixth column shows the total man-hours required for a programer to produce this material, and the seventh, the total number of months required for the preparation of the program.

FACTORS INVOLVED IN PRODUCING PROGRAMS

Why is it that a good programer can only produce 1.5-2.5 frames per hour? What does he do? In attempting to answer these questions, we can divide his tasks into seven phases as follows:

1. The preparation phase in which he defines his behavioral objectives, defines the population, and outlines the material in sequential form. (This requires about 25% of the total programing time and costs.)
2. The completion of the first draft of the programed segment. (This consumes about 30% of the time and cost of programing.)
3. Testing the original draft, usually with a few student subjects, which testing results in subsequent revisions of the major problem areas. (This takes about 15% of the total programing investment.)
4. Testing and rewriting the revised draft using a larger number of student subjects. (A cost of about 10%.)
5. Testing and revision of the third draft. (This effort represents 5% of the total cost.)
6. Final program validation. (About 5% of the investment.)
7. Final editorial work. (This might cost about 10%.)

Many industrial concerns are moving rapidly from the research phase of automated instruction into the area of direct application. Leaders and representatives of universities, industry and the military are carefully evaluating their specific training needs to determine whether or not they are ready for automated instruction. Perhaps at some time during the coming year more adequate information will be made available to assist them in making decisions of this type. Until that time, however, they must decide on the basis of information now available.

Programed Instruction: Some Economic Considerations

By STUART MARGULIES
Center for Programed Instruction, Incorporated

Many training directors have become convinced of the advantages of programed instruction. Decreased training time and increased efficiency are improvements that every company can use. Industrial training is complex, however, and it is difficult to decide where programed instruction should be introduced into the industrial-training system. The present article attempts to define the desirable characteristics of an initial course of programed instruction and provides some estimates of the costs involved.

AREAS OF APPLICATION

Programed instruction is a method of teaching; hence, in theory, it should be equally applicable to any body of knowledge. As the Mechner and Cook article (see section 1) suggests, however, subject-matter material must be broken down into small bits of information, and this information must be sequenced to lead cumulatively to increasingly more complex material. In the academic world, some subjects, such as mathematics and the natural sciences, naturally meet this requirement for automization. Others, such as theory of education and poetry appreciation, do not. Similarly, in industry, some subject-matter areas are more readily structured in a step-by-step fashion than are others.

Several of the articles in this volume, notably the staff paper by Basic Systems, Inc. (see section 5) and the several case histories, all suggest industrial applications that are best suited to the "sequential" approach. Some of the successful step-by-step industrial programs are used at present to teach such subjects as knowledge of pharmaceutical products, computer-system interrelations, billing-clerk procedures, computer language, endocrinology, and (the most common industrial program) basic electricity.

Let us assume that we are called in by an insurance company to determine which courses should be programed first. On the basis of the considerations outlined above, our first approach would be to select those courses best meeting the requirement for step-by-step development. We would select subject-areas having a large amount of factual material. In addition, for practical purposes, the courses selected would be stable members of the training curriculum, rather than ones that might be obsolete in a year or two. The courses should also be of sufficient importance to the overall training program to warrant the expense of programing.

PRIORITY OF APPLICATION

Continuing our analysis of the insurance company's training program, we find that they have a large variety of factual courses. In deciding which of these to program first, the following considerations would govern our choice:

Validity criteria. Management will assuredly demand an evaluation of the new training procedure. In many cases, however, it will not be possible to compare the new programed-instruction course with a conventional learning situation because no evaluative criteria have been developed for the conventional courses. It is important, therefore, to find those existing courses that *do* have some validating criteria. Measures such as final examination scores, number of work-items completed, or errors made on the job will be acceptable. Examinations prepared outside of the company are particularly desirable because they have a high acceptance value to management. For example, we might select a course that is followed by a State licensing examination. This will enable management to compare immediately conventional training results with those obtained with the new programed-instruction technique.

Length of course. Preparation time for programed materials can be quite extensive (estimates are given later). Lengthy courses should not be undertaken until success is achieved with shorter courses. Initial success with a short course will serve to reassure an uncertain management and to provide important feedback for longer ventures. A programed course replacing 25 hr of conventional instruction is ideal. Longer courses, on the order of one month of conventional instruction (160 training hours), should not be undertaken in the beginning.

Techniques of integration. The Hickey article (see section 7) provides many important insights into the problem of integrating the new training procedure into the existing training system. Students taking programed instruction will complete course work at different times and therefore, will not be able, to move as a group into a later phase of the conventional training situation. For example, if our insurance company presently has a 60-hr training course, it would be unwise to select the middle 20 hr of this course for programing. Because the students will finish at different times, continuation of the conventional training course will present significant problems, and using the new technique might be more disruptive than otherwise. On the other hand, if a terminal portion of the conventional classroom course is converted to programed form, and is then followed by individual field training, a more useful application will result.

Another consideration that will affect the integration of the programed-instruction course into the training system is the efficiency of the existing conventional courses. We frequently find that more-or-less untrained, part-time lecturers are used for certain course material, and the resulting efficiency of training is low. A particular attempt should be made to use programed instruction for these courses.

Rapid turnover. Programs can be very costly (estimates are given later) and, hence, should be rationalized over a large number of students whenever possible. For this reason, and for convenience, most existing programed industrial courses have been developed at the introductory level. Notable exceptions are those special courses that were developed for highly-paid personnel, typically in the upper levels of management. Training time in these instances is usually so costly as to warrant the introduction of programed material at an advanced-course level.

On-the-job training. The potential reduction in cost possible by using programed instruction for on-the-job training is an obvious advantage. In many industrial and military situations, a large part of the cost of conventional training results from travel expenses and per-diem payments incurred in transporting field personnel to centralized locations for training. Courses taught through programed instruction provide an obvious solution to this economic problem. In addition, present indications suggest that field sales representatives are highly motivated to learn from programed-instruction materials in their own time after the normal working day. Thus, sales activity is not interrupted by the time required for training.

LENGTH OF PROGRAM

It is difficult to estimate the number of frames required to translate a conventional training course into programed-instruction form. The measure of program length, however, is of basic importance in determining the preparation time (and cost) of the program. Estimation difficulties arise because programs can not be written by a simple ''translation'' of the conventional learning material to programed form. Instead, the conversion from conventional text to programed frames must be preceded by an often lengthy task analysis, in the course of which important curriculum revisions might become evident.

A good estimate of program length can be made easily if the programed material merely replaces formal company lectures. Several industrial studies have indicated that about 50 programed frames are needed to replace each hour of classroom time. This applies to representative courses, such as basic electricity or computer-system familiarization, but does not apply to curricula containing high computational components. As an example of the latter kind, a 1-hr course in payroll disbursing procedures (which requires the solution of lengthy problems) can be replaced by only 20 computational-type frames.

Although about 50 frames will provide the same material ordinarily taught in a 1-hr classroom lecture, students might be able to complete the programed material in much less than 1 hr, with a resulting decrease in training time. Several studies in secondary schools and colleges have indicated that students can finish 90-100 frames per hour, yielding a 50% reduction in training time, but industrial training applications have, more typically, yielded reductions of 25 to 30%.

PROGRAM PREPARATION TIME

An experienced programer, with the aid of staff specialists (supervisors, editors, draftsmen, etc.) can produce, typically, about 100 tested and revised frames per week. Including the time required for a preliminary task analysis, a program of 2,000 frames will require, therefore, about six man-months to complete. Additional time will be required for new, highly complex material; less time will be required for material that is similar to courses previously prepared.

PROGRAM COST

Programing companies typically charge a single fee for their services, which includes both the task analysis and the preparation of programed course material. Thus, the fee usually is quoted on a total cost basis rather than on a cost-per-frame basis. Nevertheless, it is clear that the number of frames is a major determinant of cost, and this number may be used as a basic reference unit for cost comparison. Accordingly, the cost analysis presented here is made on a cost-per-frame basis.

In the discussion of costs, program length will be set, arbitrarily, at about 1500 frames. This assumption of a 1,500-frame length is important because the cost of training analysis is proportionately greater for short programs than for long ones. In addition, other startup costs for both short and long programs are relatively fixed so that programs of greater length cost somewhat less per frame than shorter programs.

Other considerations affecting per-frame costs are the technical complexity of the course material and the availability of trained personnel. As the course material becomes increasingly more technical, the availability and training of programing personnel grows increasingly more critical and costs go up. Military material that is classified as "Secret" or higher is very difficult to handle, and greatly inflates all cost estimates.

Several other articles presented in this book, notably those by Hickey (section 7) and Ross (section 5), provide good examples of cost estimates. The cost figures given below are indicative of the currently prevailing prices. They have been obtained from polling numerous programing companies, from an analysis of representative bids made on military contracts, and from a review of present industrial contracts. These sources yield cost figures that are slightly higher than those obtained by Hickey and Ross, i.e., a cost range between 8 and 30 dollars per frame with median values between 14 and 20 dollars. These costs reflect the price for a "tailor-made" program that is suited to a particular industrial training requirement and that remains the exclusive property of the contracting company.

Proprietary rights are an important cost consideration. Programing companies are presently charging a premium of 25-150% of the basic cost of the program when all rights are the property of the contracting company. Although this premium estimate probably will remain reasonably valid for the bulk of industrial training programs, proprietary programs in basic electricity, and other courses in great demand, soon might be marketed at much less than their "tailor-made" price.

SECTION 6. Machines and Devices

To many people, the terms "teaching machine" and "programed instruction" are synonomous; the teaching machine, however, merely acts as a vehicle for presenting a program. In many cases, a machine is a necessary component of a teaching system, but in other cases, the machine can be replaced by a special type of book called a programed textbook.

Although several experiments have shown that programs teaching verbal skills can be presented with equal efficacy by teaching machines and programed textbooks, the nature of the training task often requires some sort of machine. In any event, there is justification for a teaching machine if we want to change the behavior of the learner more precisely than we can with a programed textbook. There also is a long-run economic advantage in the use of certain types of teaching machines in that the programs can be produced on media other than printed paper. These media will very often serve many more students than the usual type of book.

The articles in this section deal with the subject of teaching machines without reference to presentation by programed textbooks. The editors have attempted to collect articles that cover various aspects of teaching machine specifications, usage, and design.

The first article, by Foltz, is an overview describing many of the existing machines, both commercial and noncommercial devices. The reader will find a reasonably extensive list of devices and their descriptions. Because the field is changing so rapidly, many of the machines mentioned in this article will be obsolete or out of production shortly, and new devices will be available by the time this volume has been published. Specifications and prices will also change with improved engineering techniques and changes in the market.

Because there are so many companies involved in the manufacture and design of teaching devices, it is impossible to assume that the list given in this article is complete. There are undoubtedly companies and devices that are not represented in the article. The editors, therefore, recommend that the reader regard this article as a representative sample of current practices rather than a complete list.

The second article, by Eigen, describes the mechanics of education systems that, strictly speaking, would not be classified as implementations of programed instruction but that share many common characteristics with it. The reader interested in modifications of programed instruction for specialized training techniques will find many examples of current practice outlined in this article. As is the case with Foltz's article, ''Pseudo-Programed Instruction'' should not be considered an exhaustive compendium of current practice; rather, it is a list of some of the more interesting applications of several of the elements of programed instruction to specific types of training tasks.

The third article, by Silvern, describes a continuum of developments dealing with electronic-systems maintainence as it is influenced by performance requirements, studies of behavior patterns, technical-training requirements, and engineering-design and management philosophies. The editors have selected this article as an excellent example of the teaching machine in the context of a training problem. Although there have been many articles written on teaching machines, this particular paper will give the reader some insight into many of the types of decisions that will be required in the creation of a training system. The majority of the procedures described in this article, in the opinion of the editors, can be generalized to most training problems, and hence it is recommended that the reader regard this paper as a reasonable working model from which he can investigate the application of teaching-machine technology to many other training tasks.

The final article in this section, by Levine and Knight, briefly describes two types of teaching machines and deals with some of their advantages and disadvantages. This article will prove invaluable to anyone considering long-range plans to install equipment for teaching purposes.

Aids to Teaching: A Survey of the Current Status of Teaching Machines

By CHARLES I. FOLTZ
Electronic Teaching Laboratories, Incorporated

Technological aids to teaching can be classified in three categories. In the first are the stimulus devices, which include most audio-visual media. These assure the broadcast of material containing educational content, but there is no assurance that the educational processes will be carried out by the student. In the second, response devices, such as the typewriter, give the students a method of practicing and drilling responses but do not supply educational content. Teaching machines fall into the stimulus-response-device or third category, and add to the first two the concept of immediate reinforcement. How much this aids the student in his learning process is something that is now subject to intensive studies of various sorts.

Existing results seem to indicate that teaching machines, properly employed and programed, might considerably increase learning speed, reduce the age level at which advanced content can be presented (the Skinner method shows students complex concepts before they know what they are, and then they are slowly taught by ''augmenting'' to comprehend them), and provide a new type of motivation and/or practice for the student. Results also indicate, claim the enthusiasts, that automated instruction can compete fairly successfully with other educational methods (and, even, outside interests) for student attention. Some people in the field, however, believe that there has not been enough experimental control in existing research projects to show that teaching by an automated method is any better than the conventional method of teaching.

Two main advantages of teaching machines are their versatility and their infinite (machine) patience. Programing and designing devices for teaching industrial skills is a specialized field and an exciting market. Several firms are now engaged in testing audio-visual devices with film and synchronized tape programs to teach assembly processes. The results so far have been excellent. Programs and devices to teach incremental motor skills of this sort would be relatively easy to construct because most of the information and all of the technical knowledge already exists. This might be an excellent field to study some of the epistemological questions presented by machine teaching in view of the fact that the investment capital necessary for development is more readily available here than in the education field. Several devices and programs have been tested with preschool and "exceptional" children and have a fairly high record of success. This special problem area is one that is singularly adapted to the use of the automated tutoring method, and, again, a large-scale market (parents and institutions) seems to be a fairly immediate possibility.

QUESTIONS THAT NEED ANSWERING

Comparative studies of the different methods of programing and their applications to various disciplines are needed to make evaluations. Considering the instructional goals, what disciplines should be taught by automated teaching methods? Is it always better to minimize the number of errors in the learning process? How should the program be organized? What is the form that the response elicited should take? If cueing and prompting are to be used, what form should they take? What is the best step size considering the age level of the students and the discipline being taught? What form should feedback take: that of giving the right answer immediately after the student makes a response, merely informing the student that he is wrong and should try again, giving the student reasons why he is wrong and sending him back to choose a right answer, or giving the reasons followed by the correct response? What is the educational value of minimizing aversive reinforcement? What is lost and/or gained?

Once most of the above questions are answered, the device is almost designed. Economic questions now come into play and one must decide whether automatic scoring provides enough educational benefit to compensate for the increased cost of the device, what is the best form of presenting the program (film, paper program, etc.), and whether the device should be adapted to various modes of operation.

Certain over-all theoretical questions must be asked before the value of machine learning can be ascertained and before this method can be used to any great extent. What are the advantages of active participation, particularly in relation to student age level and I.Q.? (Dr. Lumsdaine seems to believe that they will decrease as the I.Q. increases.) How much long-term retention and transfer of knowledge learned results from the use of the automated teaching methods, and how does this compare to the present methods of teaching? What function should the teaching device have in the overall educational program? (Should it be used to *supplant* human teaching of certain disciplines?) What is the place of the teacher in the educational program if automated instruction is to be used to any great extent? (Pressey believes that teaching devices should be used only for classroom preparation, i.e., more or less automated homework machines. Others believe that all materials should be presented in the programs and/or devices. These same people cloud the issue of the teacher's functions in a nebulous haze of generalities; they say a teacher will still "inspire the answers," teach the students to think and write well, give counselling, and stimulate the student to original thinking and work. What does this mean?)

THE EXISTING DEVICES

As in any field in which rapid expansion has been brought about by the introduction and marketing of potentially profitable new products (*Electronic Industries* enthusiastically estimates a 100,000,000-dollar/year market for the next 10 yr), development of automated teaching devices (and, particularly, of concomitant program material) has been uneven. Many firms rushed to get into the field with a machine, any machine, forgetting almost entirely about programing and, even, the fundamental educational purposes for which the machines were intended.

As of this writing, there are 14 companies that produce various types of automated teaching devices and eleven that have announced that they are doing research with the intent of entering the field. There are, in addition, some 22 noncommercial devices that have been constructed and tested in classroom or laboratory work. Both the commercially available and noncommercial devices are listed, separately, in Tables 6-1-1 and 6-1-2.

A teaching machine should consist of five elements: a data storage receptacle that will contain the program to be presented to the student, a display mechanism, a response panel for either a multiple choice selection or a constructed response, some sort of feedback mechanism by which the student can get immediate knowledge of the correctness of his response, some sort of reinforcement or reward mechanism, if necessary (this may be combined with the feedback mechanism).

Teaching machines may be roughly divided into two categories, depending on the type of response (constructed or multiple choice) the student is required to make. They can be further subdivided into degrees of complexity, which include considerations of the form in which stimuli are presented, the method of presentation, and the semi-to-complete automation of scoring, operation, and feedback.

Constructed-Response Devices

In the constructed-response categories, the simplest device is one designed by Porter (see Tables 6-1-1); it is completely manu-

Table [illegible]-1-1. Commercial Devices

Company	Name	Type	Teaches or tests	Cost ($)
Applied Communications Research of Litton Industries		Individual closed-circuit TV with earphones	Manual and verbal skills such as: 1. Manufacturing assembly 2. Testing, inspection, and quality control 3. Personnel training 4. Sales training 5. Machine-tool setup	
Foringer, Inc.		Skinner roller, tapes, windows, and levers	Verbal skills	80
	Osler-Foringer Discrimination Device	Filmstrip and levers (300 frames of 35 mm film)[1]	Verbal skills in "exceptional" children	
	Miniature Display-Cell Device	Digital readout (12 lamps, lenses, and symbols)	Verbal skills such as: Wisconsin Test Apparatus studies Concept-formation studies Learning sets Oddity problems Matching to sample Multiple choice	
General Atronics Company	Auto-Tutor (designed by Galanter)	Cards and pushbuttons[2]	Manual and verbal skills such as: 1. Data-processing equipment training 2. Equipment maintenance and operation 3. Clerical training 4. Stenographic training 5. Bookkeeping and accounting 6. Sales and management training	~200

Hughes Aircraft Company	Videosonic	Slides and sound tape with earphones and multiple-choice response panel	Manual or verbal skills such as: Assembly-line procedures Basic science	
New York Institute of Technology	"Mr. Adt"	Central closed-circuit TV (or sound tape) and electric stylus in holes[3]	Verbal skills such as: Electronics Elementary mathematics Physics	
	"Mr. Adt" (improved)	Individual closed-circuit TV (or sound tape) and multiple-choice response panel[4]	(Same as above)	
Perceptual Development Laboratories	Perceptoscope	Modified movie projector[5] (no response device)	Manual or verbal skills	1,275-2,600

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[1] Correct answers are automatically and promptly reinforced by marble falling into cup between levers. After each lever movement, shutter closes over screen for specific adjustable interval, and then the next frame is presented. Answers are automatically scored on separate paper strip.

[2] Student indicates choice of answer by pressing one of four buttons on response panel: if right, new card is shown; if wrong, choice is automatically scored and card stays on screen.

[3] Two-way intercom between student and teacher and telemetering device on teacher's desk for checking answers and providing feedback.

[4] Student gets immediate feedback in form of recorded voice or answers on screen. If too many wrong answers, student is told to go see teacher.

[5] Can be used in following four ways: 1) as Tachistoscopic ("flash" projection of frames for paced practice), 2) motion picture that can be stopped and reversed, 3) "stills" (showing frames individually as in filmstrip or slides), 4) "two-film" projection (superimposing earlier sections of film on current section).

Table 6-1-1. (Continued)

Company	Name	Type	Teaches or tests	Cost ($)
Rheem Califone	"Recall" Machine (designed by Skinner)	Skinner roller, tapes, windows, and lever	Verbal skills such as: 1. Spelling 2. Introductory Psychology 3. Music Appreciation 4. *Religion* 5. European History 6. IBM Key-punch training	
	Didak 501	Skinner roller, tapes, windows, and lever (including "second-attempt" window and self-scoring attachment)	(Same as above)	
Robert E. Corrigan and Associates	Teletest	Closed-circuit TV and desk console with lights, multiple-choice response panel, and automatic scoring[6]	Manual or verbal skills	
Smith-Harrison, Inc.	Model 15	Cards, tape, and pushbuttons	Verbal skills	15
	Model 50	Programed book[7] with roller, window, dial, and pushbuttons	Verbal skills	89.50

	Model 80	Tape, roller, window, pushbuttons, and lights with automatic scoring	Verbal skills for grades six to 12	110
	Model 90	Electric stylus in holes, dial, and lights	Verbal skills such as Multiplication tables	49.50
Solartron Electronics	(designed by Pask)	Film or tape, keyboard, and small computer	Manual skill such as: 1. Typewriting 2. Keypunching 3. Adding-machine operating	
Teaching Machines, Inc.	"Min-Max"	Skinner roller, tapes, windows, and crank (similar to Skinner-Foringer Discrimination Device above)	Verbal skills	
	"19.84"	Skinner roller, tapes, window, and lever (similar to "Min-Max")[8]	Verbal skills	20

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[6] Student desk console can have coded-light signal projector that sends signals to photo cell at bottom of TV set.

[7] Programs in book form are inserted into desk-size device. Each page of book has eight questions that are shown one by one in display window as roller is turned. Student sets dial to desired response pattern corresponding to notation at top of program page.

[8] Adhesive-backed paper tape can be put over places in program where responses are to be written so that programs can be reused.

Table 6-1-1. (Continued)

Company	Name	Type	Teaches or tests	Cost ($)
	Student Film Tutor	Microfilm and typewriter keyboard response panel	Verbal skills	445
U.S. Industries	Auto-Tutor Mark I (designed by Crowder)	Filmstrip, dial (or movies) and pushbuttons (10,000 frames of 35mm film) with automatic scoring	Manual or verbal skills	5,000-7,000
	Auto-Tutor Mark II (Simplified version of Mark I)	(Same as above except 5,000 frames)	Manual or verbal skills such as: B-47 and B-52 bomb-navigation system operation Computer mathematics	~900
Williams Research Company	Science Desk	Films (16mm) and pushbuttons with automatic scoring and lights	Manual or verbal skills	

Table 6-1-2. Noncommercial Devices

Name	Designed for	Designed by	Type	Teaches or Tests
Autograph	Air Force	Rothkopf	Slides, tape, window, and pushbuttons[1]	Verbal skills
Auto-Rater	Army			
Card Sort Device		Briggs	Cards, window, keyboard, and lights	Verbal skills
Chemo-Card			Cards and stylus[2]	Verbal skills
Disc Device	Harvard	Skinner	Disc, lever and window	Verbal skills such as elementary psychology
Dynaslide	School and preschool children	Skinner	Roller, tape, window, and lever	Verbal skills such as: Elementary Arithmetic Simple readings vocabulary
Gilbert (Proposed)		Gilbert	Rollers, tapes, windows, levers, and dials	Verbal skills
Green Light Rater			Cards, window, keyboard, and lights	Verbal skills
Hively Device	Preschool children	Hively	Cards, windows[3]	Verbal skills

[1] Can be computer centered.

[2] Cards are chemically treated so that, when student marks his choice with damp sponge or end of stylus, color appears to indicate correctness of answer.

[3] Fully automatic. Right answer is rewarded by marble, bonbon, etc.; wrong answer by no change in display. Adjustments can be made to delay reward appearance, delay image disappearance, increase time between frames, reward for pre-arranged number of answers in sequence, prevent reward for simultaneous responses.

Table 6-1-2. (Continued)

Name	Designed for	Designed by	Type	Teaches or Tests
Interactive Decision-Making Assembly		Pask	Film or tape, keyboard, and small computer	Verbal skills such as: Radar-blip recognition Aircraft recognition Elementary mathematics
Memory Drum Device		Pressey	Tape on drum, window, and levers with automatic scoring (newer model has pushbuttons)	Verbal skills
Meyer Device		IBM	Skinner roller, tape, window, and lever	Verbal skills such as elementary mathematics
Omar Khayam Moore System	Preschool children	Moore	Filmstrip and electric typewriter	Verbal skills
Polymath	Air Force	Rothkopf	Tape or slides with stylus and tracing arm[4]	Verbal skills
Porter Device			Skinner roller, sheet, window, and lever	Verbal skills
Punchboard Devices		Pressey	Punchboard, sheet, and pencil	Verbal skills
		Freeman	Electric punchboard, stylus, and lights	Verbal skills
		Roth, et al.	Film or tape, typewriter keyboard, and computer (IBM 650)	Verbal skills

Self-Rater	Navy		Tape on drum, window, lights, and multiple-choice response panel with automatic scoring[5]	
Subject-Matter Trainer	Air Force	Briggs	Tape or slides, lights, buzzers, and multiple-choice response panel	Verbal skills
Tab Item Device			Sheet with tabs	Verbal skills such as diagnosing malfunctions for repair in electronic equipment
Wiemar (Proposed) Device		Wiemar	Closed-circuit TV or movies with loudspeaker or earphones and typewriter keyboard and computer	Manual or verbal skills
CLASS		SDC	Closed-circuit TV, keyboard and bar, and computer[6]	Verbal skills
		SDC	Slides, typewriter, keyboard, and bell with computer (Bendix G-15)	Verbal skills

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[4] Can require one, two, or three of following responses: multiple-choice responses; constructed responses consisting of words, phrases, or numbers up to 29 symbols long; tracing responses with such items as maps or circuit diagrams (auditory signal indicates when student departs from correct path).

[5] Fully automatic.

[6] Teacher can dial any student number and receive from computer complete information on student's progress at any point in program.

ally operated. The data are scored on a single slip of paper, with five responses required, which are to be written on the program itself. Feedback is provided by moving the answer up under a glass shield (''cheatproof'') which also brings the correct answer into view on the display slot. The disadvantages of this arrangement are that the students can look at the program and answers before inserting them into the machine, and, because the students write on the program itself, it may not be re-used. A further disadvantage is that the student is required to score himself so that, in actuality, the device is by no means ''cheatproof.''

Slightly more sophisticated devices of this type have been designed by Skinner and others. They are also manually operated, but the commercial devices can hold about 1/2 - 1 hr of programed material, which is locked into the machine so that the student cannot ''peek'' at the answers beforehand. They are still not ''cheatproof'', despite such items as a ''non-cheat spring'' (which prevents students from moving the response tape in order to rewrite their answer), because they are student scored. Most of these devices can, at some extra expense, be made completely automatic in operation, but, because the basic drawbacks and mode of operation still remain, this would be an undesirable expense.

The manually-operated Skinner device (Dynaslide) to teach basic arithmetic (see Table 6-1-2), and a similar, commercially produced, device that is electrically operated (Smith-Harrison Model 80), add new features to the basic device structure. Similar to the aforementioned devices in other respects, they are so geared that when a wrong response is made, it is impossible to move on to a new problem. In addition, each incorrect response is automatically scored (on a dial on the side of the Skinner device and on a separate strip of paper in the other).

Gilbert has suggested a modification of this basic Skinnerian device. He would have a program on paper presented through a display window, and the student would answer with a constructed response written on a separate piece of tape. The student operates a device to open another window that displays 12 possible answers. He then dials the number of the answer (on a device supplied at the side of the machine) that most closely corresponds to his own answer. This drops a new frame into the display window. Thus, this device provides for a branching program that is dependent on the student's own response.

Rothkopf's Autograph is less automated, but it introduces a new mode of stimulus display. The stimuli are presented on slides on a screen in front of the student, and, when the student has completed writing in his answer on a separate sheet of paper in the device, he rolls it up under a glass plate that, at the same time, removes a cover over a section of the slide to reveal the correct response. The student then scores himself. The display is regulated by an instructor who is hidden from the student and who can change the program sequence according to the information he receives on the student's accuracy of response. This leads us into various other, more complex, intrinsic programing devices.

Roth, Anderson, Perli, and others propose highly complex machines using an automated ''little-man-in-the-box'' technique. The) display can take the form of either a written program or, more likely, a filmed program. Responses are made on a typewriter keyboard and the answers fed into a computer that analyzes the answers character by character. The computer then informs the student of the correctness of his response and analyzes instantaneously the student's problems and needs, and then programs accordingly. Such a system would be tremendously expensive, but the expense would be somewhat reduced by having a single computer handle a number of student positions simultaneously. Such a device is currently only in the research and development stage and the enormous problems of programing the computer to handle the system have not yet been precisely worked out.

Multiple-Choice-Response Devices

The range of devices in the multiple-choice-response category is even more diverse because of the greater technical ease of checking multiple-choice answers. The simplest devices are manually operated, student scored, and extremely simple in operation. Under this category, comes Pressey's punchboard device. The student puts a question sheet over a perforated block and punches a hole through the paper next to the answer of his choice. If the pencil penetrates, his answer is correct. The Chemo-Card also comes under this category. With the Chemo-Card, the student marks his choice with a damp stylus. The paper is so treated that the mark turns a certain color if correct and another color if incorrect.

Pressey's Memory Drum Device has the additional features of machine scoring (number of incorrect responses) and provision for preventing the student from continuing the program until he has made the correct response. When a question is answered correctly, it will be dropped out of the sequence. Similar in principle, although somewhat more complex, are the Army's Auto-Rater, the Navy's Self-Rater, and the Green Light Rater, as well as Brigg's Card Sort Device. These differ in data-storage capacity, the type of display, and the method of feedback. Information as to the correctness of answers is provided by a green light for a correct answer and a red light for an incorrect answer.

These lights are geometrical in shape, such as a circle and a triangle, to cope with the problem of color blindness.

Much more complicated devices have been designed by Crowder that operate on intrinsic program principles. The Tutors, of Crowder design, present data on film. The student sits at the console and can dial motion or still sequences. According to his response, he is told to select a certain frame, which he then dials and continues with the program. The data-storage capacity on these two devices is 10,000 and 5,000 frames of 35 mm film, respectively; this would be sufficient for many hours of student operation.

Another Rothkopf device, the "Polymath" utilizes a paper-program display device. This device also can have a human operator or a computer to correct answers and provide feedback to the students. The computer or human operator chooses the slides to present to the student on the basis of the student's response and provides feedback by means of vari-colored lights that indicate the validity of his response. The unusual thing about this device is that it has 24 multiple-choice buttons arranged in an open square around a constructed-response panel. On this panel can be placed a map outline or some similar material that the student is required to trace with an electric stylus. If the tracing is correct, the electric stylus completes a circuit, and the student gets immediate knowledge of the correctness of his response.

Devices for Preschool and "Exceptional" Children

In a somewhat different category are several devices that are designed to teach preschool or "exceptional" children concept discrimination. These have a display panel and only two or three choices of response. The Hively machine has a large display window in which the program appears. Below it are two smaller display windows containing stimuli items to be compared or contrasted. To make a response, the two lower display windows themselves are pressed. The other devices have similar displays but separate response panels consisting of multiple-choice buttons. The student is asked to match or discriminate between the pictures presented in the two windows below the display window from which the image is presented. In doing this, they learn various concepts such as the concept of shape (triangles, etc.). With proper programing, this machine could also teach reading. First, the written word could be presented in the display window and similar words given in the lower windows. The child could be asked to match these. Then a picture of the object (e.g., "cat") could be presented in one of the lower two windows with different words appearing in the other and one of them identifying the object. Research is being performed on programing devices such as these by the Devereaux schools for exceptional children. A Yale sociologist named Omar Khayam Moore is doing research in teaching preschool children how to read and write. He uses a screen and a slide projector to project the images and has the child reproduce them. As the program increases in complexity, the child is required to identify objects and write down the words that correspond to them.

Another interesting device developed by Dr. Moore is one to teach preschool children to type and take dictation. To do this he paints the finger nails of each child in individual colors. Then the keys that are to be used by each finger are painted in colors to match. Drills and programs are presented either on paper or by a slide projector. The typewriter is so modified that, if the child makes an incorrect selection of a typewriter key, the key will not depress. Dr. Moore hopes to connect his system to a computer that will program automatically for each individual child. He has had singular success with his devices, although his experimental group was quite small. He was successful in teaching a three-year-old child to print after 14 weeks, and he has a seven-year-old child typing and taking dictation using simple vocabulary.

The two most interesting facets of Dr. Moore's work are the age at which a child can be taught to read and write, and also the fact that, for machine teaching at least, it is much more simple to teach printing and typing than it is to teach handwriting. This suggests a revolutionary concept. That is, that handwriting might be outmoded as a writing technique. In the interests of facility of learning and legibility, it would be much simpler to teach a child to print and, perhaps, to type.

Devices for Industry

Then there are devices designed for industrial use that are mainly for the teaching motor skills, some coupled intellectual skills, and drill in both of these. The simplest is the manually operated, student-scored Tab Item device for training in electronic trouble-shooting. The student is given a symptom of what is wrong with the machine he is being trained to repair. He then must go through a written series of possible operations and checks he can perform and select the ones he thinks most relevant to the problem. At the end of each check is a slot covered by a tab. If he pulls the tab, he will be given the result of making such a check. The aim is to get through the program with the minimum number of tabs being pulled necessary to the logical diagnostic pattern used in repairing the machine.

Another company is marketing a modified film projector, and a number of programs related to industry on film. This device utilizes lecture and example techniques, and infrequent tests are also projected. The tests are answered by the students on separate answer sheets that are provided. This is a student scored device; the film gives the answers immediately after each test.

Hughes Aircraft and Applied Communications Research Systems have designed training devices for assembly processes. These consist of televised film displays and synchronized audio material (which each operator listens to through earphones). The operator goes through the described procedures as he watches and listens to them. The Hughes system is currently in use and, it is claimed, has yielded a great increase in efficiency, an even greater decrease in defective assemblies, and an improvement in morale (which is not entirely due to the "appropriate industrial background music" that comes through the earphones when instructions are not being given).

Finally, there is a separate group of devices designed by Gordon Pask of Solartron Electronics, Ltd. These are intended to teach the use of the IBM key punch (Hollerith), the twelve-key adding machine, and to practice and teach typing. All these devices use computers to do the programing. They are based on the Rothkopf "little-man-in-the-box" technique. Essentially, the trainee plays a game with the machine. The machine paces the student, increases the speed of stimuli presentation, and the difficulty of exercise, always staying a little bit ahead of him. Pask reports that the motivation to learn in this manner is tremendous, and that trainees have stayed at these devices long after the training time is over. The trainees report that they enjoyed working with the devices but that they often worked so long that they were "bone weary" when they stopped. Such devices adjust to the individual problems and idiosyncracies of each trainee individually and are the closest approximation to a personal teacher-student relationship that has yet been devised in the automated field. The reinforcement mechanism consists merely of the challenge of playing the game with the machine. There is no feedback except in the form of recognizably simpler or more complicated material and accomplishment.

The Language Laboratory

The language laboratory as a teaching machine is a special problem intrinsic to the instruction of all oral language. All stimuli, responses, and consecutive feedback or reinforcement require a special type of programing. A straight-line program is necessary, and the device must be student scored and corrected. To correct each student individually would involve a tremendous amount of time, and, at the present time, the most sophisticated and automated scoring device is a machine that has a vocabulary of only 15 words. To aid student scoring, a device has been suggested by which the student introduces a high-frequency tone into the tape wherever he has made an error. He then plays back the tape at a high speed, and when the tone is hit, the machine slows down to a normal talking speed.

Rand Morton at Michigan University is working on an advanced language laboratory. His system will consist of a very large language laboratory with a dial system in each student booth. The student can dial any one of a number of programs in different languages at different levels that are being continually broadcast. Sooner or later, he hopes to have some sort of synchronized visual device that can teach the written language in conjunction with the spoken one. The student will be presented with the written word on a screen, it will be repeated several times, and he will be asked to reproduce it on some sort of constructed-response mechanism on the desk in front of him. Eventually, this might be used to teach the student the grammatical rules and constructions of the language as well.

The Programed Textbook

The simplest teaching machine of all is the programed textbook. There are two types of such textbooks: one requiring a constructed response and the other one requiring a multiple-choice response that leads into an intrinsic program. Books of the former type have been designed by Homme and Glaser and the latter, introduced by Crowder, is designated a "scrambled book". Not being automated, there is no method of making such material either "cheat proof" or scored in any way other than by the student himself.

Several tests have been made that compare the merits of programed textbooks and teaching devices employing programs. The studies that have been made indicate that students learn equally well from a programed textbook as they do using a teaching device. This raises the question of whether student scoring is any better than automatic scoring by the machine. Many devices have sacrificed automatic scoring mechanisms in the interest of economy, but economic considerations are not the only ones. The less opportunity the student has to circumvent the learning process by cheating, the more efficient the learning process becomes. The use of a machine requires the student to follow the prescribed order. If he uses a programed textbook he might be able to take the easier items first and to look over the whole program and decide what he wants to complete and what he does not want to complete. This procedure would negate some of the benefits to be derived by this method of teaching. Furthermore, some sort of overt response is required from the student. He must either construct a response or select one but certainly not copy one, which would be possible if he were using a programed textbook.

In spite of initial appearances to the contrary, the teaching-device enthusiasts argue with some logic that it very well could be more economical to use a device than to use a programed textbook. The argument goes something like this. After the initial outlay for the purchase of devices, the maintenance should be minimal. Programs can be used and reused by a great number of students in most of the teaching devices that now exist. The programed textbook, however, will contain some additional material that provides feedback to the student, and might, therefore, be more expensive to produce than the machine program. In addition, most textbook programs cannot be used over again because the student is required to make overt responses on the pages of the textbook.*

Device enthusiasts thus argue that teaching machine costs might be made up, in a reasonable amount of time, in savings from the decreased expense of buying programs. The greater cost of programs, and the greater number of programed textbooks required from this point on, make the programed textbook more costly than employing any but the most expensive devices, so they say.

SELECTING THE DEVICE

Each of the component parts of a proposed teaching machine must be studied in relation to the program and, particularly, to the disciplines to be taught before the device is constructed. As far as data storage is concerned, the devices that employ television screens certainly need none. Film and slide devices are more expensive to produce, but the film or slide is more durable than a paper program and offers more flexibility in display.

Data-storage capacity depends on whether films or paper programs are used. Ideally, a device should contain enough program material so that the teacher or, particularly, the student would not have to be bothered by having to make frequent changes that would interrupt the learning process. A small data-storage capacity is the main fault of the Porter device and the Pressey punchboard devices and constitutes a lesser drawback in the Skinner disc device and the Pressey memory drum.

The display should be centrally located, in easy view, and have some logical connection with the response panel (e.g., the display on the Pask device to teach the use of a twelve-key adding machine resembles the adding machine keyboard). Up to a certain point, the larger the display the better. The mechanism of the display depends entirely on the material on which the program is presented. Film, although expensive to produce and display, probably provides the best method of displaying programed material because of the greater number of items that can be presented on each section, the flexibility of being able to display either single frame or motion picture sequences, a greater durability, and the enhanced attractiveness of the display.

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*Editor's note: Some publishers, aware of this problem, are providing separate answer booklets to partially overcome this difficulty. Books, however, are comparatively limited in their durability when compared with film or other media.

The response panel should be designed to be easily accessible to the student and should be of simple enough construction so that the student can master it in a short period of time and be able to concentrate his attention on the display. If it is too complicated, as in the Polymath device, the student will spend time making his selection that he should be employing to study the program. The Tab Item device, of course, is merely composed of a response panel that actually presents the skill to be drilled and, so, is an exception to this rule.

There have been no studies of multiple-choice-response devices that indicate the optimum number of responses that should be made available to the student. Probably three or four would be sufficient variety without being overly complicated if the device were so designed to continually change the response pattern. Otherwise, the student would continually press the same button or figure out the response series without bothering to learn anything at all.

In the constructed-response devices, the responses should be made (and generally are) on a separate strip of paper. This allows the program, if it is a paper program, to be reused and proves a type of detachable scoring record for each student. If the response is to be constructed on a typewriter keyboard, or in some other manner, the same considerations should apply as those for the multiple-choice-response devices.

At this point it is necessary to digress a bit and discuss the various modes in which a device can be used. The Subject Matter Trainer, despite other deficiencies, was useful in making a study in how best to use a teaching machine. Groups of students worked with the Trainer, each receiving feedback in a different manner. The following methods were used:

1. The coaching mode (as soon as the question is presented, a light appears next to the correct answer).
2. The single-error-permitted mode (the student is allowed one choice only and then the correct answer is shown).
3. The practice mode (the student is allowed to continue mak-

ing responses until he selects the right one, and then the question is changed.

4. The single-try mode (the student makes one choice, is immediately informed of the correctness of his answer, without necessarily receiving *the* correct answer, and then the device moves on to another question).

5. The paced practice mode (the student is allowed only a certain amount of time to make a response before the new material is presented).

6. The test mode (the student is allowed only one try before new material is presented, and there is no knowledge of results).

It is unfortunate that, although most of the devices employ one or the other of the modes, only two limited studies have been made as to their relative efficacy. The conclusions reached in these studies were that the single-try and the coaching mode provided the best learning retention. However, the studies differed as to which of these two was the best one to employ. The mode used should be the one that will most effectively implement the program. For example, the paced-practice mode is used in the training devices designed by Gordon Pask to train operators in the use of IBM key-punch and adding machines and to teach typing.

There are two basic methods of giving the student information about the correctness of his answers. Some of the devices designed by the armed services and others depend on lights to show the student whether his response is correct or not. This appears to be wasted movement. The student must look away from the display to find out data on his response, and he must go through the, admittedly simple but uneconomical, mental operation of translating the lights into the concepts of right and wrong. The majority of the devices provide feedback data by showing the right answer in the display slot. This would seem to be the best method because such data should in no way detract from the student's attention to the program and the stimuli provided.

In both methods of programing, the feedback data is used either to reinforce a correct response or to correct an incorrect one. This is done in the branching technique by providing a new explanation for a misunderstood principle and then sending the student back to try to get the right answer (the practice mode). Using the Skinnerian technique, the student is allowed one attempt and then immediately provided with the right answer (the single-try mode). However, some Skinnerian devices do not allow the student to continue the program until he has made the correct response. This also is a utilization of the practice mode.

The significance of employing a teaching device in various modes can be found by a study of the reinforcement theory of learning. To learn, the right answer, and only the right answer, must be reinforced. If the correct answer is made, the student receives reinforcement by being allowed to continue the program, or, in the Crowder branching method of programing, by receiving a programed, verbal "pat on the back." If the student makes an incorrect response, he receives the aversive reinforcement of not being able to continue with the program, having the point re-explained to him, or such reinforcement as is provided by a device such as a light or a buzzer. The more rapid the feedback, the more effectively the learning is reinforced and retained. The drawback of most manually operated machines is that, in normal operation, they exceed the 1/2-1/10 sec optimum interval for feedback.

Reinforcement generally is provided by the success of answering a question correctly and being allowed to continue with the program. Some of the devices to teach preschool children allow for additional reinforcement by dropping out a marble or piece of candy for each correct response or a given number of correct responses. Most people in the field believe that the amount of aversive response should be minimized. Devices that incorporate buzzers or lights to reinforce aversively a wrong probably do some damage. Additional reinforcement can be provided at small extra cost in many devices by allowing for the disappearance of questions that have been answered correctly once or twice.

WHAT OF THE FUTURE?

There is, at this writing, an established need for improvement of the quality and quantity of domestic education. According to a report of national goals of the Office of Education, the present teacher-to-student ratio in the continental United States is about 1 : 24 and, over the next 10 yr, the situation will gradually worsen. Some of these teachers must be eliminated from consideration because of poor qualifications. National Education Association statistics show a shortage of 135,000 teachers, 100,000 teachers with substandard credentials, and 44 million students enrolled in 1960. These statistics also indicate that the situation will grow worse as time progresses. Existence of a growing scientific body of information concerning the learning process and the technological advances in this country should be combined and utilized in the education field. Education is still, in the main, oriented towards the horse and buggy era and has not really begun to make the most of our national resources.

Norman Crowder stated in an interview in the *Saturday Evening Post* that "By the mid-1960's most systematic teaching in U.S. schools and colleges will be done by teaching machines and programed textbooks." Plans are being presented already for student consoles that will incorporate the following devices: visual display screens that use material from a motion or slide projector and that will be part of the student console or that can be hooked into closed-circuit educational television networks, tape recorders for oral language learning and speech therapy work, and general-purpose teaching machines that are adaptable to the teaching of any number of disciplines. Some special consoles might even include oscilloscopes that would enable a language student or a speech-therapy patient to study his responses and attempt to match them with patterns formed by the instructor's responses shown to him on the display screen. These and many other devices can be used to aid in the learning process.

Pseudo-Programed-Instruction Systems

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The application of the *principles* of programed instruction are numerous; they reach to many types of media and a wide variety of learning tasks. They can be applied to individuals or large groups. In many cases, equipment and procedures are general, but specific applications often require specific engineering in the mechanical and psychological senses. This article describes some of these; there are undoubtedly many others, and the future will surely produce a myriad of applications of programed-instruction techniques to public education and military and industrial training.

KEYBOARD TRAINER

A pseudo-programed-instruction system has been developed to teach the manual skills involved in keyboard operation. The device, known as SAKI (Solartron-Rheem Automatic Keyboard Instructor) was developed jointly by Solartron Electronic Group, Ltd. and Rheem Manufacturing Co. for training keyboard operators. Almost any type of keyboard operation can be taught by means of SAKI.

Essentially, SAKI consists of three units: a control unit, a display unit, and the keyboard (see Fig. 6-2-1). The keyboard is identical to the one that the student will use on the job. The display unit is composed of two panels that can be illuminated from the rear. The lower panel is a diagram of the keyboard. The upper panel is a translucent screen on which four rows of characters can be printed. These characters (numerals, letters, or symbols) include the complete range of characters available on the keyboard.

The operation of the SAKI has been described as follows:

"The pupil sits in front of the machine, and, when it is switched on, a light . . . appears behind the first character in the first line of the upper translucent panel of the display unit. The . . . character . . . indicates that the pupil is to depress the key representing this character. To help the pupil identify the correct key, a light also appears behind . . . the appropriate key on the lower display panel. When the pupil depresses the key indicated, the lights on both display panels will be extinguished, and another light will appear behind the second character in the row containing the exercise . . .

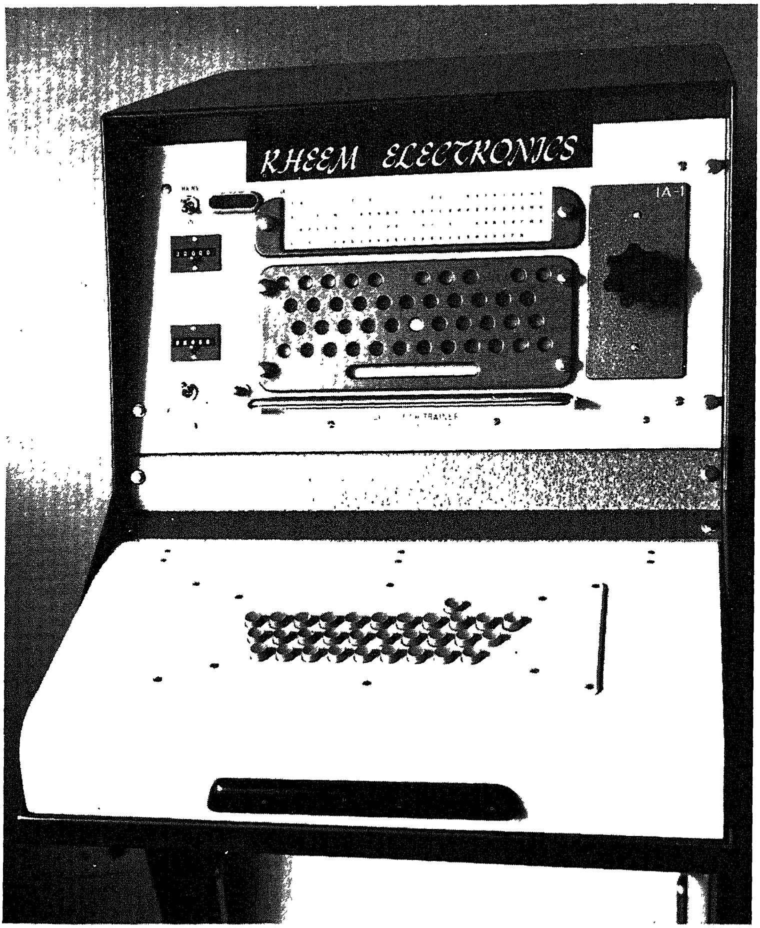

Fig. 6-2-1. Solartron-Rheem Automatic Keyboard Instructor (SAKI)

". . . As the response of the pupil becomes faster, the rate at which the characters in the exercise are presented by the machine is increased automatically. As the pupil becomes even more proficient, the lights that appear on the lower display panel begin to get dimmer until, finally, they go out . . . Sooner or later, she will make a mistake and depress the wrong key. Immediately . . . the machine slows down and the lights showing the correct keys to be pressed reappear."*

**A Machine That Learns From Experience, Data Processing*, April-June, 1959, pp. 108 and 109.

Thus, the student receives immediate confirmation of the appropriateness of his or her response. The machine determines with what speed and with what accuracy the student must complete the first line before being shown the second line of the upper display panel. Many sets of upper display panels are prepared. When the student completes one, he goes on to the next. In general, these sets become progressively more difficult.

As with the teaching machine, the student is required to make an overt response. Unlike programed instruction, however, SAKI is not completely student paced. With true programed instruction, the student has control over the speed of his training and instruction; neither machine nor program have control over the speed with which the material will be presented to him or the speed with which he will respond. Even in cases in which time allowed for training is a critical factor, the pacing is relatively immaterial. In training keyboard operators, however, pacing is critical in that the desired terminal behavior, which is the ability to operate the keyboard, is judged in terms of both accuracy and speed.

In most verbal learning, and in many manual skills, it is immaterial how fast the actual response is made. Within limits, the duration of time that elapses between the stimulus and the response is also unimportant. For example, if a salesman is asked by one of his potential customers about the characteristics of one of his products, a second or two delay in giving his response is not at all detrimental to his sale. In the case of the keyboard operator, however, a one-second delay in making each response effects the efficiency of the entire operation. Hence, in the case of keyboard operation, speed is an integral part of the training task.

Pacing in the SAKI is an interesting combination of student and machine pacing. Preset standards of accuracy and speed must be reached for mastery, but the manner in which the student reaches these standards depends on the speed and accuracy which he develops during the learning task.

PRODUCTION-LINE TRAINER

Another type of system that has many of the characteristics of programed instruction has been developed for use in industrial production. The objective of this system is to produce work of high quality under controlled conditions. This type of system consists of a small audio-visual unit that presents pictures in the form of projected 35mm slides with a concomitant audio message presented through earphones. The machine informs the employee visually and orally of the production procedure he is to carry out. The employee then performs the work in the prescribed manner. When he decides that the work is completed, he goes to the machine to be informed of the next step to be taken. One of the features of a device like this is that it can be paced by the student or by the machine. In other words, the employee can control or be controlled by the delay between steps in the production sequence.

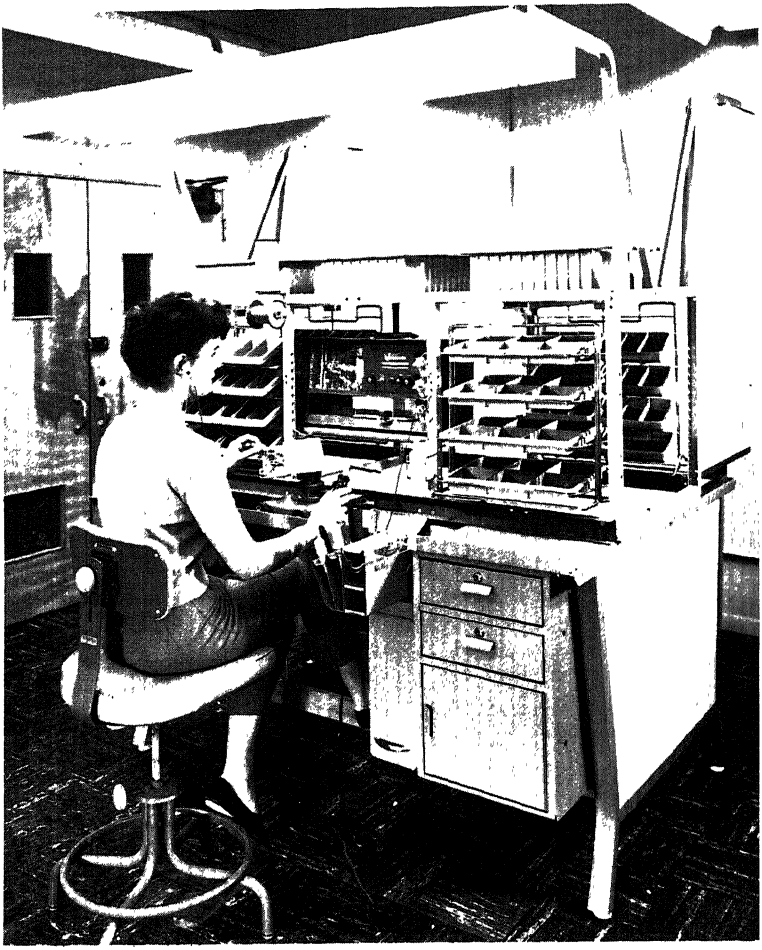

Fig. 6-2-2. Hughes Videosonic Teaching System

Devices of this type have been manufactured by Hughes Aircraft (see Fig. 6-2-2), Applied Communications Systems division of Litton Industries, and Graflex and LaBelle, just to name a few. Like teaching machines, these devices also must be programed. In particular, the production task must be broken down into small increments and presented to the employee so that he can perform the appropriate task with a minimum of error.

The usual type of reinforcement, that is, confirmation of correct response, generally is absent in this type of system. The success of the program is almost completely determined by the skill with which the programer has broken down the steps and successfully used strong prompting techniques. It should be emphasized that the prompting techniques, as contrasted with the usual teaching-machine techniques, need not be withdrawn. It is not necessarily desirable to have the employee perform without the aid of the machine, though in point of fact, this would probably happen after a while. The whole program can be highly prompted, and recall is not important because the machine is always present. This latter fact makes the job of programing considerably easier in many ways; the withdrawal of cues and provision for reinforcement contingencies are not necessary.

This type of system is of special value for production of equipment that is fast becoming obsolete. Procedures along the entire assembly line can be changed from day to day for the new improved version of the product merely by programing the changed aspect and replacing the old slides and tapes.

It also should be pointed out that this type of device also can be used as a Skinner-type audio-visual machine. Thus, it can be used in training tasks for which response to an audio stimulus is the desired terminal behavior. Training of telephone operators would be an example of this. The tape can simulate a customer calling the operator, and the visual panel can present form charts and reference material that the operator would use in dealing with the customer. The operator can make some sort of response and then receive confirmation as to the appropriateness of the response on the next slide and next audio message.

TROUBLE-SHOOTING TRAINER

Another type of system that has been used for instructional purposes is the "trainer-tester". The "trainer-tester" consists of a printed sheet that might have a paragraph stating the trouble for which repair would be necessary, a list of possible remedies (for example, "Replace tube V-5.") and, next to each possible remedy, an aluminumized tissue that has been pressed on top of the paper. The trainee can erase the tissue opposite any of the possible remedies. When he does, information is revealed as to whether or not the instrument would operate properly with the particular remedy chosen.

The student decides what remedies to select by studying a list of symptoms. The list of symptoms consists of numbered connections in the circuit where meter readings might be taken. Next to each possible meter-reading point is an aluminized strip that, when erased, reveals the meter reading that would be taken at that point in the defective instrument. For example, the trainee might decide to measure the potential drop across resistor V-5. The student then erases the appropriate portion of the aluminum strip and discovers that the potential drop across that resistor is 3.2. On the basis of this data, he makes a decision as to what type of remedy might be appropriate and then makes an erasure in the list of possible remedies. When the trouble has been "fixed," he is so informed. Thus, the trainer-tester technique provides practice in trouble shooting without requiring expensive and possibly unreliable equipment.

The reinforcement contingencies that can exist with the "trainer-tester" depend on the way in which it is programed. On initial practice sequences, if the student erases an aluminum strip in the list of symptoms that would give him data irrelevant to the trouble, the program might inform the student that he chose irrelevant information. Later, this could be "faded out" so that he would get some data, regardless of where he had erased in that section. He would, however, receive reinforcement as to the appropriateness of his choice until he had made an erasure in the list of remedies.

Different military organizations have used the "trainer-tester" in experimental situations. The following quotations concern the "trainer-tester" report of the officer in charge of U.S. Navy Guided Missiles School at Virginia Beach: "A definite saving in time is accomplished in that each trainee may be assigned the same trouble and work at his own speed . . . Where there is no need to physically install the trouble in the equipment, there is always a savings of time. A saving in material results in not having to solder and unsolder connections . . . Wear and tear on parts and equipment for which the "trainer-tester" is substituted is reduced to a minimum since the equipment need not be used in trouble shooting.

"Due to the fact that so many different troubles can be introduced to the trainee in a given length of time, he can develop definite habits for trouble shooting that improve his ability to analyze troubles and proceed in logical steps to their solution and correction."

Preliminary data from the atomic-weapons-training group at Sandia Base in Albuquerque, N.M. indicate that the mean time per problem for correct action on the "trainer-tester" simulator was 13 min. The training task thus is facilitated by enabling the trainee to avoid the soldering and unsoldering of connections and all those time-consuming activities that are not directly related to the problem at hand.

The use of the "trainer-tester" is certainly not limited to electronics trouble shooting; it can be used for trouble shooting in other areas such as engine maintenance and repair and problems of logistics management. It also could be used as an answer sheet for a standard multiple-choice-type teaching-machine program—erasing the appropriate aluminum strip would confirm the fact that the student had selected the appropriate response.

COMMON CHARACTERISTICS

The aforementioned three types of systems have several characteristics in common with programed instruction. It should be noted that each of these techniques developed from a need to solve specific categories of training problems. In the case of SAKI, the training problem was keyboard operation. In the case of the "trainer-tester," the general area was trouble shooting. Whereas programed instruction can be applied to many areas of training, the three aforementioned pseudo-programed systems are limited in their application. SAKI, for instance, could not be used in the training of salesmen. The trainer-tester technique would not be applicable for the training of keyboard operators.

One reason for these specialized techniques being developed is that programed instruction is not a suitable solution. Most of the techniques in programed instruction have been developed to solve problems in verbal training and education. In general, reinforcement for appropriate responses is provided for in a verbal type of program by having students make the response and compare it (or have it compared by a machine) with the programer's version of the correct response. It is extremely inefficient, for instance, for the keyboard-operator trainee to do this. In point of fact, this is exactly how a person learns to operate a keyboard without any training program whatsoever; he strikes a few keys, looks at the sheet of paper in the typewriter or the IBM card and determines if, indeed, this is what he wanted to type.

PROVIDING REINFORCEMENT

The two major problems in utilizing programed instruction for any type of manual training, whether it be keyboard or production, are in providing for proper reinforcement contingencies and in providing for branching possibilities with a number of alternative actions far greater than the usual three, four, or five. In training for tasks that involve the use of specific equipment, it is usually very difficult to provide for the proper reinforcement contingencies. It is easy to tell the trainee, for example, to "clamp the piece of work into the lathe and turn the clamp tightener marked A in your diagram," but we are not at all sure that what he tightens is the clamp tightener. There usually is no method for the trainee to get feedback from the device as to the appropriateness of any phase of the operation. This is particularly true when operation of the device requires many suboperations before the trainee can tell whether or not he has done the right thing.

So far, there have been two methods developed to handle this type of problem. The first is designing a piece of equipment that will sense the appropriateness of the response; this piece of equipment then could be used in conjunction with the unit that the trainee is learning to operate. (SAKI is an illustration of the use of this technique.) But the use of this technique often requires intricate sensing instruments that must be specially devised. This is usually expensive and, in many cases, not justifiable in terms of the training value gained for the dollar expended.

The "trainer-tester" is a simple example of the second method —use of simulators—to solve this problem. Simulators and sophisticated sensing devices have been combined with very effective results (the Link trainer is an excellent example of this). The combination is usually quite expensive, and it is certainly more desirable to use a technique such as the "trainer-tester" if it is applicable. For training in the use of many pieces of equipment, the trainer-tester technique is more efficient, but it usually would not be used to develop many skills.

A third possible solution to the problem is to use a modified version of the device that the trainee is being taught to operate in conjunction with a standard teaching-machine-type program. The device would be essentially that which the trainee would be taught to operate but would have modifications so that the reinforcement he receives can be provided for in the program. An example of this technique is a program to teach elementary-school students how to use a microscope. Such a program has been written at the Center for Programed Instruction and has proved extremely effective in developing the necessary skills on the part of the students for microscope operation.

The program is used in conjunction with a specific training microscope. This instrument essentially is like the microscope the student would normally use except that the different parts have been color-cued, that is, each essential manipulative part of the microscope has been painted a different color. Thus, the program can now say to the student: "Put your hand on the focus knob. What color is it?" The student can respond by writing the word for a color in an appropriate answer space and then receive confirmation as to the appropriateness of the word he wrote. If the focus knob were blue and his response were the word "red", then the correct answer that would be given in the program would be: "Blue, if you wrote any other color, you have the wrong part."

The instrument or parts thereof can be modified so that the student can do his own sensing. For example, if the student were instructed to focus a normal microscope and slide, we would have no way of knowing whether or not he did focus the instrument, but if we use a specially prepared slide with the microscopic words "in focus" printed on the slide, we can ask the student to turn the focus knob until he can read the word. We can then make the assumption that when he can read the words "in focus," he has successfully focused the microscope.

PROVIDING ALTERNATE RESPONSES

The second major problem is that of providing a large number of possible responses. Theoretically, a Crowder-type scrambled program could provide for all possible responses, but this would necessitate an extremely bulky program, and its sheer size would be overwhelming. Its large storage capacity and easy access to the storage makes the electronic computer a natural solution to this problem, but this solution involves considerable expense. Thus, the trainer-tester technique seems to give the most efficient solution to this problem when one considers the time, effort, and expense. Unfortunately, however, the "trainer-tester" cannot be applied to many important training situations.

GROUP INSTRUCTION

The discussion so far has been concerned with individual instruction. There are many possibilities of using some of the *principles* of programed instruction for group instruction or mass communication. One such system has been developed by Teleprompter Corp. for lecture halls and closed-circuit television.

Programed instruction usually features the overt response of the learner, and the programer can adjust his behavior (that of writing the program) on the basis of the student's responses. Teleprompter has developed an "answer back" pushbutton control unit (see Fig. 6-2-3) by means of which each viewer throughout the entire closed-circuit system can respond to multiple-choice questions shown on the screen. The same type of "answer back" control units can be installed in seats in the lecture hall so that each member of the audience has the opportunity to make an individual response to the questions presented. Thus, the programer or lecturer can change his behavior (adapt the program)

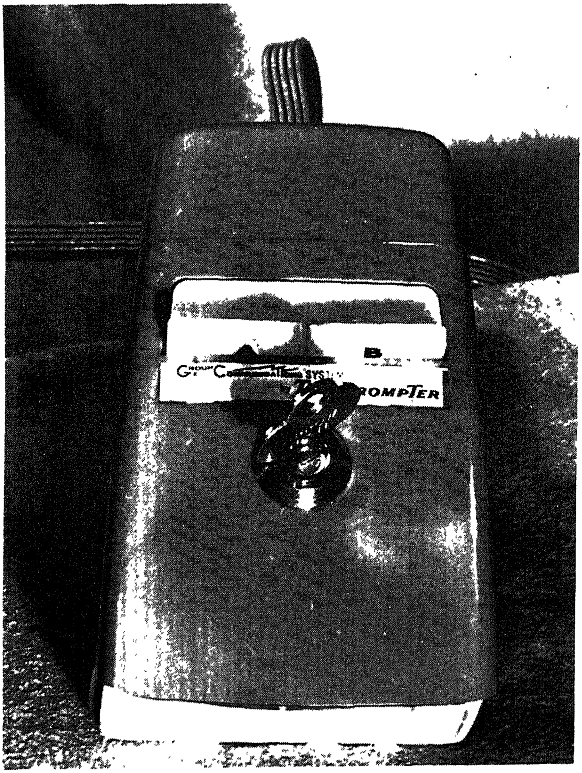

Fig. 6-2-3. Teleprompter "answer back" pushbutton control unit

on the basis of the student responses, which he can read off a percentage meter either at the lectern or in a TV studio. It is also possible, for mass-viewing purposes, to plug each of the "answer back" control units directly into a computer that can score tests and/or do some sort of item analysis for program-evaluation purposes.

Another characteristic of the Teleprompter system in lecture halls is the preplanned program. The lecture hall can be equipped with several random-access, rear-screen projection units, which can project combinations of images on the screen, and a rear-screen motion picture projection unit or, if desirable, a closed-circuit, rear-screen-projected television set. The lecturer can control the presentation by means of a specially wired lectern.

It is also possible under the Teleprompter system to have the lecturer read his material from a continuously moving Teleprompter in the lectern. It is further possible to have a presentation of the different visual materials completely controlled by the movement of the teleprompter script; when the lecturer reaches a certain point in his presentation, the appropriate material will be flashed on the screen. As a further sophistication of the system the lecture, as well as its controls for visual material, can be put on tape, and instruction can be given to a large group of students without the physical presence of the instructor. The Teleprompter system has been used by several of the major universities in the United States, and the University of Wisconsin in particular has experimented with presenting fully controlled tape recorded lectures through the system (see Fig. 6-2-4).

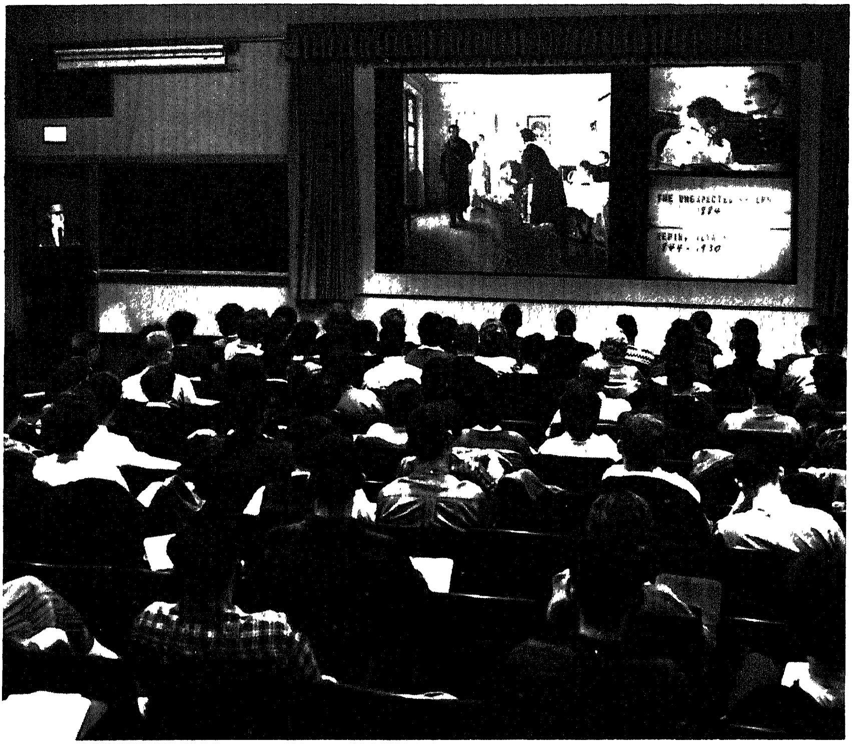

Fig. 6-2-4. Teleprompter installation at the University of Wisconsin

The United States Army also has used Teleprompter installations for educational purposes at Redstone Arsenal. Experimental data from the Ordinance Guided Missile School at Redstone have shown that, in an acquisition and computer course for the Nike-Hercules missile, there was no significant difference between the so-called "conventional" courses and those taught with the Teleprompter system, but there was a time savings, in using the Teleprompter system, that ranged from 16% with some units to 41% with others.*

Although the Teleprompter system has many of the advantages of programed instruction, it also shares some of the disadvantages. Relatively high programing and production costs for the system can be justified only in terms of the number of students reached and/or the number of times the presentation is given. Unlike programed instruction, however, the Teleprompter system retains one characteristic of any type of group instruction, that is, students can not proceed at their individual paces. Nevertheless, this type of system demonstrates how equipment can be designed and utilized so that many of the inherent disadvantages of group instruction can be overcome. Although it does not retain all of the aspects of programed instruction, the Teleprompter, as a pseudo-programed-instruction technique, does provide many of the advantages of true programed instruction.

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*Training by television and television prompting equipment, Army Ordinance Guided Missile School, Redstone Arsenal, Alabama, February, 1959.

The Influence of Teaching-Machine Technology on Electronic-System Maintenance Training

By LEONARD C. SILVERN
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Our society is moving continually in the direction of complexity. This complexity thrusts upon us the responsibility for understanding and controlling it. Teaching-machine technology suggests a way to more quickly assist us in acquiring the knowledge and skills we must have in an increasingly complex society.

Of all the machine systems with which we are familiar, one kind in particular is troublesome because of its increasing complexity: electronic systems. Electronic systems seem almost to generate intrinsic problems as they satisfy extrinsic specifications. This article describes a continuum of developments dealing with electronic-system maintenance that have been influenced by performance requirements, studies of behavioral patterns, technical-training requirements, and engineering-design and management philosophies. In the discussion, reference will be limited to the intrinsic problems of electronic-system maintenance that are created as new and different equipments and instruments are produced.

A MAN-MACHINE RELATIONSHIP FOR MAINTENANCE

There are at least two ways in which one can think about maintenance: designing maintainability into the system at its conception and shaping the behavior of human maintainers to provide maintainability after installation. This delineation follows closely the basic ideology of Taylor with respect to man-machine systems involving the operator of the machine rather than the maintainer (Taylor, 1960). He reminded us that it was during World War II that the approach of designing the task to fit the operator was added to the more traditional psychological procedures of selecting and training operators to fit their jobs. This was necessitated by the variety and complexity of military equipment. Machinery had finally outran the man's ability to adapt, and the

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recognition of this fact was, in Taylor's view, the first important insight in the development of engineering psychology. It is regrettable that very little emphasis was given to designing the equipment for maintainability.

The man-machine system concept probably grew from an extension of the weapon systems and control systems notion in engineering. And as Taylor has said, the concept made obvious the fact that one could not design the mechanical portions of a system of which the man was a part without knowledge of the characteristics of the human component for operating purposes. His analysis of man-machine systems into two areas, each dealing with a different objective, is worthy of review; one class of systems is constructed to affect the condition of the human in that system. An example is the learner and his teaching machine. The purpose of inserting the nonhuman element into the system is to improve the well being or efficiency of the human within the system. The other class of systems is conceived as one which alters the environment or changes relationships between the system and other entities external to it. The pilot and his plane illustrate this class. With these systems, Taylor believed the dependent variable of greatest interest is a measure of the performance of the total system and this measure reflects the combined performance of all the components in the system, not that of the human alone (Taylor, 1960).

It is obvious that the human component of the man-machine systems defined by Taylor involves human operators and not human maintainers. While he did feel that in addition to controlling, the human collects information, filters, stores, and evaluates it, applies rules to it and makes decisions, these functions were in the operational frame of reference. One might suggest that a man-machine relationship might exist in the interaction between a system and its maintainer—particularly with reference to fully automatic systems which have no human operator but which do have periodic preventive maintenance or malfunction maintenance performed.

THE DESIGN ASPECT OF MAINTENANCE

There has been some awareness by engineering administrators and designers of the total problem of electronic systems maintenance in terms of maintainability and reliability (see Folley and Altman, 1956). This approach, of course, deals with equipment configuration rather than personnel training. Folley and Altman identified solutions to this problem by recommending design practices which would maximize the ease with which electronic systems can be maintained. The self-test circuit and checkout console and the computer diagnostic routine, fault isolation program, and test routine are recent examples of design techniques to improve the engineering aspect. It was felt in 1956, at least, that maintainability requirements for electronic equipment were extremely vague as compared to the detailed performance requirements usually specified (Folley and Altman, 1956). In referring to trouble shooting procedures, Folley and Altman believed that systematic procedures should be provided since technicians would frequently use inefficient or even dangerous practices if efficient procedures were not provided.

The problem described by Folley, Altman and others concerned with maintainability in the armed forces technical organizations was anticipated somewhat earlier by several practitioners who also had visibility. Notable among these was Miller, who, in 1953, summarized several prior investigations concerned with both the design and personnel aspects of system maintainability (Miller, 1953). With regard to design, he contended that the following three principles governed equipment design:

1. The design of new equipment is also the design of new jobs (operator and maintainer).
2. Equipment performing complex operations can be designed for easy operation and easy maintenance).
3. Dependability and maintainability in realistic field conditions should enter into the decision to approve designs.

He was of the belief that planned simplicity in the maintainer's job needed to be stepped up and made more systematic.

Nadel, in his capacity as Secretary of the Advisory Panel on Personnel and Training Research for the U. S. Department of Defense, wrote in 1955 that the maintenance of electronic equipment was a major military operation for each Service, and that equipment failure could mean the difference between victory and destruction. Equipment failures, he pointed out, could be attributed as much to the very complexity of the equipment itself as to other factors (Nadel, 1955).

In general, some effort has been made to improve maintainability through design. Equipments with digital computer systems or subsystems are often easier to trouble shoot in so far as localizing the malfunction is concerned, if the proper maintenance routines are programed. But the effectiveness in trouble shooting still appears to be largely a matter of individual human skills, according to Ely, Hall, and Van Albert (1960). Trouble shooting remains in the province of human decision and action, in the opinion of the author, and will continue there for awhile, at least so long as the equipment which trouble shoots a system will itself need to be maintained.

And what portends for the future when man is in space? Jones, in his remarks on Mercury at the 1959 American Psychological Association convention (APA, 1959), pointed out that studies were being conducted to reveal the types of difficulties that are apt to occur before and during a mission by estimating what failures are apt to occur in the systems and components. The mission is automatic, and the only time the human has a significant role beyond the scientific one is when there are problems in system operation. Failures of the component, effect on system operation, sensory cues, instrument cues, and corrective actions may be available both to the ground personnel and the astronaut. These can be used, Jones avers, to determine the procedures that the human must accomplish and, probably most important, to define the nature of the diagnostic tasks he must perform. Since similar constellations of signs may appear for fifty or sixty different failures, these must be differentiated to decide the proper corrective action for the specific failure.

THE PERSONNEL ASPECT OF MAINTENANCE

Assuming that the engineering designers will make a superhuman effort to produce reasonably maintainable equipments, we can now turn from the non-human to the human category and be concerned with the maintainer, leaving a discussion of the operator for another time. Miller's initial interest in the early 1950's centered about the development of methods for predicting and anticipating job requirements for maintainers. Accurate forecasts would suggest early training programs so competent maintainers would accompany the system to its operational environment. The Air Force AN/APQ-24 Radar and the K-1 Bombing-Navigation System were used for early studies (Miller, 1953). Some of the significant observations he made in 1953 were as follows:

1. There is a need for early knowledge of the job activity or behavior for maintenance through systematic analysis.
2. Knowledge of job activity produces information dealing with job relevance.
3. Training devices and instructional materials can be produced from job activity and job relevance data.
4. Ability to read technical orders and translate them into job action is a requirement common to all technical jobs.
5. Knowledge basic to design is not necessarily basic to maintenance.
6. Research is necessary to determine the information most effective in performing maintenance and the ease in learning this by the maintainer.
7. A complete, clearly written set of job instructions may actually take the place of training.

8. A major revision of current technical vocabulary with simplicity as an objective is necessary.
9. Specialists in human factors and in training should assist in planning the equipment design for maintenance.

This series of studies which began in 1950 and was terminated in 1956 contributed to the newly emerging systems maintenance philosophy by identifying problems and proposing solutions. The Air Force Qualitative Personnel Requirements Information (QPRI) program, in its formative stages, benefited from this effort. It was concluded that job requirements for maintainability could be forecast and used as a basis for planning personnel and training programs in an orderly manner. However, the studies suggested that additional investigation was required in developing procedures whereby contractors could provide for earlier planning through more intrasystem coordination in the development of design specifications, functional data-flow diagrams, and ground support equipment (Miller, 1956).

THE 1955 SYMPOSIUM ON ELECTRONICS MAINTENANCE

In August 1955, the Department of Defense conducted a symposium bringing together practitioners in the military systems maintenance field. Hall, of the Navy Electronics Laboratory, expressed the view that the operational effectiveness of man-machine systems may be considered as a multiplicative function of the ideal potentialities of the equipment (potentialities as viewed by creating engineers), performance potentialities of the human operator using the equipment, and effective maintenance. He cited a 1950 study which showed that only 33% of Navy electronic equipment was operating satisfactorily at that time, and disclosed that 9% of electronic equipment in Fleet Units was inoperative and 65% was operating poorly or improperly in 1955. Hall thought that the problem of millions of failures was serious not only because of the cost in billions of dollars but also because of the decrease in operational effectiveness and provided these facts to support his view: a certain type of complex airborne electronic equipment required over three hours of maintenance for each hour of flight; one-third of the Air Force operating cost is for maintenance and one-third of their personnel is engaged in this activity, although over half of their maintenance is done by contractors; the cost of maintaining electronic equipment in the Air Force is about twice as much per year as the initial cost; maintenance cost during the life of Navy equipment is ten times its initial cost (Hall, 1955).

Carstater, of the Bureau of Naval Personnel, pointed out, in establishing a frame of reference, that while proficiency in trouble shooting was probably the hallmark of the electronics maintenance technician, the symposium was concerned with electronics maintenance activities such as inspection, calibration, adjustment, as well as trouble shooting. In a very loose sense, he thought, trouble shooting and repair are necessary only when other maintenance activities have failed (Carstater, 1955).

In the opinion of Irvine and Smith of the Navy's Personnel Research Field Activity at San Diego, the personnel problems involved in maintaining Navy electronic devices differed from those involved in maintaining devices in the Army or Air Force. Land-based organizations were able to have their technical personnel specialize in the kind of work and in the type of equipments, but the sea-going Navy was limited in the amount of shredding out (organizational specializing) that could be done. Space limitations and relative isolation of the ship as an operating unit require a small number of highly skilled electronics technicians to maintain a wide variety of electronic equipments. The problem in 1955 of properly maintaining the Navy's electronic systems was due primarily to a shortage of trained technical personnel—the result of a shortage of qualified civilian recruits, the long training period necessary to qualify, and the low re-enlistment rate. The problem was summarized by saying that "too much is required of too few" (Irvine, 1955).

Earlier, it was pointed out that the functions of operator and maintainer were uniquely distinct. However, the Navy did identify certain maintenance functions with the human operator (Irvine, 1955). This practice reemphasized the need for a more analytical approach to the job to be performed rather than the man who performs the job. There had been too little concern with the need to study the job independently of the man. There was an awareness of the need to determine the knowledges and skills required for each essential task, then sort the tasks requiring similar knowledges and skills into functional groups or packages. This confirmed Miller's observation in 1953 that detailed knowledge of job activity was essential (Miller, 1953). It will be seen that the concept of job analysis, which is essentially the result of studies of job behavior patterns, seems to permeate the discussions and studies of maintainability down the years to and including 1961.

The Army in 1955 did not face this problem with the same magnitude as did the other services, yet the awareness of solutions did exist. Karcher, of the AGO's Personnel Research Branch, believed that while selection procedures and similar personnel research efforts of long-range orientation should not be overlooked, research in job analysis, training content, and training methods would have a more immediate payoff (Karcher, 1955).

Gagné, of the Air Force Personnel and Training Research Center, in reviewing the work of Miller and others in AFPTRC, said that the Air Force development philosophy was that a weapon system is a man-machine system and that many detailed directives had been issued which have the aim of ensuring that planning for the man would go hand-in-hand with development of the equipment. The importance of determining the so-called Qualitative Personnel Requirements for newly developed weapon systems was apparently receiving extensive recognition throughout the Air Force. He summarized his thinking about job analysis in the following terms (Gagné, 1955):

1. Information about job requirements for new equipment comes from equipment designers who have in mind—but not necessarily in recorded form—the activities required for maintenance. Recording this systematically during early development remains a problem.
2. Job requirements for maintenance can be predicted early in the development of new equipment, and these tend to remain stable as production is reached. The points of correspondence between predicted job behavior and actual job behavior remain to be explored.
3. Terms used in describing jobs must be understandable, reliable from job to job, and meaningful for selection and training. To meet these criteria requires a detailed, behavioral description. What seems to be required and yet undeveloped is a set of operational definitions of behavioral categories.

The Navy had prognosticated the problem of job behavior patterns very early in the spectrum of time and engaged members of the Department of Psychology of the University of Southern California to intensively study this area. Actually, the Navy Department had used crude job analysis techniques in the early days of World War II to establish training programs for existing and newly emerging trades, crafts, and technical occupations. The author, when faced with the task of establishing a technical training program for Navy civilian employees in June 1942, adapted trade and job analysis techniques used in vocational schools for this purpose (Silvern, 1948 and Greenly, 1943). There is evidence that Allen, between 1910 and 1919, and Selvidge in 1923, published occupational analyses in the form of jobs and operations composing jobs from their experiences in World War I (Graham, et al., 1943 and War Manpower Commission, 1945). This was succinctly stated in 1943: "instructional material for all vocational teaching should be based upon an analysis of acceptable performance of what a practitioner of the vocation does.....the testing program involves three types of tests.....oral test is a quick method of checking the why of the job.....written test.....to measure the related technical information.....performance test measures skill, the ability to do, along with how to do it....." (Graham, et al., 1943) and again in 1945: "job analysis or the making of job breakdowns is an important preliminary step before instruction" (War

Manpower Commission, 1945). One can readily conclude that job analysis was not really new, but the techniques of obtaining dependable job behavior information and detailed job requirements in the electronic systems era in sufficient time to support the systems operationally had yet to be formulated.

Bryan, of the University of Southern California, presented at the 1955 Symposium an evaluation of various job analysis methods as an outgrowth of Navy-sponsored research there (Bryan, 1955b). It was his contention that surprisingly few comparisons of job analysis methods had been published and that published material contained descriptions of general procedures. When an investigator needs to define, describe, or assess the requirements of a particular job, it may be necessary to develop new job analysis methods or to modify existing ones.

As a result of research in using a number of job analysis techniques, he had concluded the following:

1. No single method will produce all the information required to adequately describe a job. The compromise is a combination of methods which supplement information that can be collected easily with a large measure of concentrated on-the-spot observation.
2. There is definite need for more intensive study of specific methodological problems inherent in job analysis in order to specify more completely the limits of each method.
3. The role of job analysis in our modern complex organizations is too crucial to allow its methods to remain in the realm of the arts.

The 1955 Symposium, while very clearly concerned with job analysis, was in agreement that maintainer training techniques could spell the difference between success and failure. Wischner, Barch, and Hammock of HumRRO concluded that Army technicians regard school training highly; after experience on the job, can offer constructive suggestions concerning the relevance of the school curriculum; needed more training in systematic trouble shooting; needed more training in practical trouble shooting exercises, routine checks, adjustments, and location of parts; and more practice in use of block diagrams (Wischner, et al., 1955). Technicians found circuit analysis and equipment construction instruction of low job applicability. One of the most significant general findings was the virtual absence of systematic on-the-job training programs in any of the maintenance areas studied. In addition, the Navy experience with operators performing certain maintenance functions was supported by the HumRRO team which noted that of all the malfunctions obtained, in approximately 50% symptoms were first observed and reported by the operators (Irvine and Smith, 1955). These operators also assist the mechanic in preventive maintenance.

Carstater, of the Bureau of Naval Personnel, concluded that there is a very real need to obtain greater continuity between school training and on-the-job learning (Carstater, 1955). Much that is known about how men learn, how to teach, course construction, school plant design and operation, supervision of instruction, adaptation to individual differences, diagnosis and remedial instruction—much that is available in the science and art of teaching is not being effectively brought to bear in solving the training problems of the Military Services.

Carp, of the Air Force Personnel and Training Research Center, in a discussion following a paper, said "I am quite ready and willing to take an extremely critical look at most of our training activities and ask the question, 'Are they really training for the job?'" (Carp, 1955).

THE 1956 FIRE CONTROL SYSTEMS TRAINING CONFERENCE

On 2 May 1956, a Fire Control Systems Training Conference was conducted by the Air Force at Lowry Air Force Base (USAF, 1956). McKinney, of Air Defense Command, had established a correlation between training and the overall results of the fire control system and asserted that maintenance was handicapped by the extreme shortage of maintenance personnel. He compared fire control systems maintenance training with the weather, saying that everybody talks about it, but nobody does anything about it. There has been talk for four years, but very little concrete action to improve it.

Up to now, no mention had been made of the human instructor aspect of maintainer training. Turpin, of Lowry Air Force Base, directed his attention to this problem echoing similar experience of varying magnitude in the other services. He believed the instructor corps was frightfully inexperienced, both technically and professionally, and this was attributed to turn-over rates; i.e., failure to re-enlist and transfer to other Air Force units. Under circumstances in 1956, there was no relief in sight. He suggested that maintenance of complex electronic systems was not beyond the learning ability of most of the airman recruits, but that development of skills in both mechanics and technicians was fast becoming beyond the teaching abilities of instructors. Unless a change in the way instructors were selected and developed, classroom efforts, in his view, appeared doomed to a plateau of mediocrity. It seemed to him, as a civilian educator, that too many failed to realize that a successful instructor must acquire a dual proficiency—in the job performance he teaches, and, from an educational point of view, in the developmental teaching process. The author had recognized the dual role of the instructor as described by Turpin and had identified knowledge of subject and communication as instructional ability in a course in training technical instructors for the Navy Department and had refined it into technical competence and instructional competence by 1956 in a textbook dedicated to engineers who were called upon to instruct electronic systems maintenance without prior instructional experience or training (Silvern, 1948 and Silvern, 1957). Later, in 1957, this had been further analyzed to technical competence (knowledge of engineering, weapons systems and lesson) and communicative competence (use of lesson plan, integration of learner materials, participation, communication, knowledge of trainees, integration of training devices). In addition, managerial competence and personal characteristics were similarly described (Silvern, 1960).

Gagné, representing AFPTRC, raised an interesting question at the conference. Would it not be preferable, he said, in view of the heavy demands on skilled manpower which modern weapon systems make, to be sure that all possible means have been exploited to make the learning of these skills a fully effective process? Would it not be preferable if the limits of what training could accomplish were more certain? He announced that plans to conduct research to determine principles governing the effective use of training equipment, particularly self-instructional devices (teaching machines), in the area of MG-10 maintenance training had been formulated (Hughes, 1956 and Briggs and Duvall, 1957). The basic requirements for these might be the following:

1. Measurement of the student's performance.
2. Exploitation of various attractive ways of feeding back this information to the student.
3. Maximal use of the student's natural interest in competing with himself or with his fellows.

Gagné had reason to believe that this simple everyday kind of motivation could make a tremendous difference in students' performance.

At the conclusion of this conference, Renshaw of HQ, USAF, felt that the Air Force was placing increased emphasis on the critical problems which apply not only to fire control systems maintenance but to all complex equipment coming into the inventory in the future.

It would appear that the equipment was becoming more complex, at least in terms of maintainability, the instructor corps did not generally meet the total requirements of the services for one reason or another, and much was yet to be learned about job behavior in the tangible form of job analyses.

NAVY RESEARCH AT THE UNIVERSITY OF SOUTHERN CALIFORNIA

The Office of Naval Research by 1950 had reached the conclusion that the job behavior of Navy electronics technicians, particularly when involved in localizing malfunctions or trouble shooting equipments and systems, was still not well understood either by engineers or psychologists. In view of the alarming increase in the electronic systems inventory, the Department of Psychology at the University of Southern California was asked to organize a research effort and, in the eight-year period beginning late in 1952, over 30 technical reports were published dealing with the conclusions of very carefully organized and controlled experiments. This is an ongoing general program to analyze objectively the job of the naval electronics technician, but it was quickly found that the trouble shooting aspect of job behavior was a highly desirable skill which required special training and special study.

Much of the early effort consisted of shipboard observation of electronics personnel while performing their duties in the destroyer environment. As a result, several tests were designed by 1953 which measured various aspects of trouble shooting proficiency. One of these, the MASTS, was the multiple alternative symbolic trouble shooting test. Later, with a mechanism for automatically recording the subject's responses, it became the AUTOMASTS. In essence, these tests replaced both electronic equipment and test instruments in a trouble shooting situation by the use of a symbolic format. In March 1955, it was reported by the Electronics Personnel Research Group that the experimental evidence thus far suggested these conclusions (Bryan, 1955a):

1. A test battery had been developed which was useful and dependable in selecting a criterion of electronics technician technical competence.
2. Identification of trouble shooting goodness is related to availability of adequate performance records such as produced by AUTOMASTS.
3. Electronics trouble shooting is a very complex process.
4. Traditional division of electronics into subject-matter areas was more for convenience of the trainer than as an indication of an essential structure.
5. The AUTOMASTS portion of the proficiency test battery appeared to have definite potentialities as an advanced trainer for shipboard use.

In the opinion of the writer, the efforts of AFPTRC in developing and improving simulators, as described by Gagné and others (USAF, 1956; Hughes, 1956; and Briggs and Duvall, 1957), were directed towards training while the ONR-USC research began with the development of proficiency testing devices. Yet both produced apparatus and programs which by 1956 were, in fact, teaching machines and teaching machine curriculums. It is very curious that both these developments dealt with maintainability of electronic systems, thereby testifying to the early awareness by distinguished investigators of the applicability of teaching machine technology in this field.

In 1956, Bryan and others summarized their research in electronic trouble shooting, which dealt with sequential records of trouble shooting behavior, integration of trouble shooting information with analytic approaches, and general statements about trouble shooting; sixty-two conclusions were published (Bryan, 1956). The implications for future activity supported the concern of those in the field of electronic systems mentioned earlier. It was believed that the problems were difficult but would yield to persistent effort, that fundamental units and categories for coding behavior needed to be systematized and elaborated, that continued contact with trouble shooting in real work situations rather than ivory tower environments was mandatory, and finally that the systematic framework was all the more important as electronics becomes increasingly important and pervasive in its military and civilian applications. The personnel problems would grow in scope and urgency.

In 1959, Bryan and Schuster reported on research dealing with training technicians to efficiently trouble shoot a complex electronic system when cookbook procedures had failed (Bryan and Schuster, 1959). The experimental design was directed to compare three magnitudes of structuring: no assistance, guidance on steps to take, complete guidance. In the no assistance part, learners were required to work through printed Loran trouble shooting problems without assistance. In the guidance on steps to take part, a specially constructed device called OST (Optimal Sequence Trainer) was used to acknowledge correct decisions and prompt; it was used together with an information book. It had a feature of special interest: if a decision was not forthcoming in seven minutes, a prompt would be given. This particular timed technique has been considered for purposes other than maintenance training (Silvern, 1961 and Silvern, 1957). In the complete guidance part, learners were required to conform rigidly to a preordained path. The implications were revealing: in developing supplemental trouble shooting training procedures, it appeared that excellent use could be made of a kind of teaching machine since results indicated a properly constructed device could greatly improve training. Using the principles developed from the experimental evidence, the authors concluded that the

Navy would be able to fill a real gap in its present trouble shooting training programs by using teaching machines.

In September 1960, addressing the Human Factors Society, Rigney stated that it was not likely in the immediate future that unscheduled maintenance could be designed out of equipment or that fault location could be completely automated. He and his colleagues believed that the most important implication of this and related research conducted by others is for the revision of present-day procedures in electronics training schools. The chief advantage of the teaching machine was that it would provide a way of giving learners a tremendous amount of guided experience in a short time by relatively inexpensive means. It seemed to the USC group that it was not so much a question of the superiority of the machine instruction over traditional classroom methods; rather it was a question of giving this training in electronics maintenance at all (Rigney, et al., 1960).

MAINTAINER'S BEHAVIOR AND TRAINING SOLUTIONS

The Air Force, like the Navy, was aware of the need for detailed knowledge of electronic system maintenance behavior motivated by similar reasons. For a number of years the American Institute for Research had served a similar function for the Air Research and Development Command at the University of Southern California. The work of Miller, Folley, and Altman, introduced earlier, at AIR, when coupled with the research and development at AFPTRC and WADD as evidenced by the work of Briggs, Gagné, Besnard and many others who deserve mention for their contributions, represents a magnificent contribution to behavioral science in general and maintenance training in particular. Unlike the research at USC, the AFPTRC effort was simulator or training device-oriented. The Subject Matter Trainer, E-4 Fire Control System Simulator, E-4 Fire Control System Trouble Shooting Trainer, MG-10 Radar Procedural Trainer and the MG-10 Computer Procedural and Trouble Shooting Trainer, were no longer audio-visual aids or perhaps not even simulators as they began to deviate from instructor-centered to learner-centered devices. This transition to teaching machine technology began very unobtrusively about 1945 and was virtually complete when the Subject Matter Trainer and the two MG-10 devices were produced by Briggs, circa 1955-57. These were described by the author as the pseudo-simulator and more recently by Levine and the author as one form of the teaching machine growing from the training devices continuum (Silvern, 1957; Levine and Silvern, 1960; and Levine and Silvern, 1961). There is no question that the criteria for teaching machine technology apply to these AFPTRC devices regardless of the names by which they may have been identified.

In August 1959, Briggs summarized his long, persistent and productive study of training devices and teaching machines in electronic systems maintenance (Briggs, 1959a). He stated that the need is crucial to analyze complex skills to establish the knowledge components and it was only recently that maintenance had become sufficiently demanding to justify the same magnitude of research effort which for years had been directed to pilot training. He felt that curriculum development had to be improved in terms of proficiency outcomes. Briggs saw in 1959 the need for verbal or classroom teaching machines and maintenance teaching machines, i.e., certain machines with a great usefulness for classroom type knowledge and others obviously able to more effectively simulate equipment yet retain all the criteria for teaching machine technology. He also was aware that engineering design could reduce maintainability skills requirements to a point where, in some systems, very little practice of maintenance during training would be required. He further described the two different kinds of teaching machines as the educational kind of machines for information acquisition and concept development, while special simulator teaching machines may provide practice in integration of job knowledge into job task performance (Briggs, 1959b). Briggs believed that these maintenance teaching machines were expensive but did provide learning the actual motor performances which he felt were the criterion behaviors and the end products of the intellectual activity of the trainee. And he was not at all convinced that results obtained in training operators contained the answers to the questions raised for maintainer training programs.

Others investigating the use of trouble shooting training devices for the Air Force, which were obviously forerunners of the teaching machine of the maintenance variety, were encouraged by the outcomes. Tucker, in using a K-system trouble shooting trainer with decreasing or fading guidance by an instructor, concluded that it was a "reliable, practical and effective substitute for the actual equipment.....(overcoming objections) that trouble shooting can be learned only by experience on the job, that the mechanics must be trained on actual equipment that is in excellent operating condition, and that a very considerable amount of training time is required" (Tucker, 1955). Newman and Highland had concluded, in an investigation of the effectiveness of instructional materials and methods which would minimize the role of the instructor in teaching electronics, that the use of aural-visual devices such as the recorder-slide combination would prove useful particularly if the materials could be adapted to the needs of the learners by preparing several different levels of the same lesson (Newman and Highland, 1956). Stave observed that as Air Force equipment became more complex, the training devices also increased in complexity with a tendency to provide progressively more automatic features (Stave, 1960). In tracing the evolution of military training devices, he pointed out that various methods were evolved to lighten the instructor's task; one method was automatic recording of critical student responses.....this was, in his opinion, the beginning of the present trend toward automaticity in training devices. His seven-step evolution is based upon a human scoring-machine scoring discretum.

Not all investigations or investigators in electronic systems maintenance have concluded that teaching machines—or even simulators—hold the final solution. Folley examined the work of Smith in which documents were used for trouble shooting (Folley, 1959a, Folley, 1959b). The technicians had virtually no training and only nominal aptitude. A specially prepared job aid in document form was successfully used to trouble shoot. He reported that the trouble shooting tree approach was being scrutinized and referred to Miller's 1953 anticipatory statement that written job instructions might replace training (Miller, 1953). It appeared to Folley that all the facts that have been learned on teaching machines can now be applied to the design of textbooks that include the learning process sequence but he was also aware of the limitations in maintenance where the acquisition of skills requiring dynamic displays and part-task perceptual-motor skills was necessary.

The Army, too, is aware of the growing complexity of its electronics inventory. Smith recently declared that HumRRO studies have shown the value of the functional context method in training maintenance technicians (although he does not further identify maintenance in terms of the kinds of systems) which consists of job-oriented context, graded series of job-related tasks, and a whole-to-part sequence (Smith, 1960). He stated that the greatest importance of automated techniques in training deals with the possibility of applying basic principles for efficient learning. Rupe presents, in 1960, the same fundamental problems of complexity, length of maintainer's service, predicting training requirements, obtaining job information, as were identified earlier in 1955, admitting that these were not particularly novel or startling (Rupe, 1960). His argument is basically that a detailed task and skill analysis of a total man-weapon system (both personnel and hardware subsystems) could be made, reduced to coded form, stored in data processing form, made available for modification information and used for many purposes, but the most challenging requirement will be that for identifying the information essential for formal training. Whitmore was concerned with job behavior and thought there were many best guesses being made which had to be studied and went on to describe the possibilities inherent in teaching machines (Whitmore, 1960). Mager believed, on the basis of his research, that while it is possible to impart many of the skills related to electronic maintenance, this could not be accomplished with a single programing method or with simple teaching machines (Mager, 1959). He saw a need for more sophisticated machinery for teaching the skills associated with the maintenance of complex electronic equipment. On the other hand, Kanner concluded that the area of automated teaching devices is one where scepticism should prevail until more evidence and experience have been accumulated (Kanner, 1960).

A SYSTEMATIC APPROACH TO TEACHING MACHINES FOR MAINTENANCE TRAINING

It is not the intent of this paper to provide detailed research findings or describe the wide variety of mechanisms known as teaching machines, this has been done. In addition, there is little to be accomplished in discussing the various methods of developing teaching machine lesson plans, the practical value in transferring experimental conclusions determined from teaching five-year-old children molecular science in the first grade to training 30-year-old 7-level Air Force technicians in trouble shooting the MA-11 Digital Computer Subsystems, etc. The fundamental issue the writer raises is: can teaching machines be used to train maintainers in performing preventative and corrective maintenance of complex electronic systems? Questions as to the superiority or inferiority of a machine, the cost of obtaining and maintaining a machine, the magnitude of human acceptance of or resistance to a machine, the logistics.....all of these will have uniquely distinct answers in different frames of reference.

The weight of evidence appears to suggest strongly that teaching machines can train humans to proficiently maintain complex electronic systems. In order to achieve this objective within reasonable limits, practitioners should consider the guide points described in the following paragraphs.

Maintainability Design at the Engineering Stage

Engineering and physical science curriculums in colleges and universities generally avoid providing detailed instruction which would result in a strong maintenance design philosophy. As institutions of higher education tend to stress fundamentals, even in graduate schools because there are so many new fundamentals, they depend upon industry to train in the applications of these principles. Industry has assumed this role and, through formal training programs or supervised experience, attempts to develop such philosophies. Quite often, because of rapid expansion of the organization, the supervision may be provided by an engineer with only several more years of experience than his subordinates. With this pooling of ignorance, the maintenance design philosophy can be pretty weird. No, a philosophy to be good should come from the systems-oriented engineers with experience—these are usually in the engineering management layer. But finding the man there is not the end, it is only the beginning, since engineers are notoriously poor communicators and changing the man to manager does not magically make him one. One can conclude therefore that sound maintainability design must be planned and specified as an integral and fundamental engineering requirement irrespective of engineering management competence. In fact, this competence must be acquired, if necessary, to satisfy the customer's specifications. The technical specialties most familiar with maintainability problems should contribute to drafting the specifications and approving designs. Engineering psychologists, behavioral engineers, technical training directors, and other hybrids who have been maintenance oriented are in this category of specialization (Holland, 1959). Every effort must be made to design and manufacture a system which minimizes the need for corrective maintenance and has nominal preventative maintenance. Systems which by design are difficult to maintain will present equally difficult job behavior problems which, in turn, will create nearly insurmountable teaching machine curriculum problems. Training is not always the real solution—quite often better results can be obtained by early engineering decisions or by early management decisions rather than by after-the-fact training programs.

Job Information and Behavioral Patterns

When electronics consisted mainly of communications-type equipments, that part of maintenance called trouble shooting was pretty straightforward or, as some have said, from the middle to one end! From the fantastic variety of new components, trick circuits, microminiaturized packages, modular designs and strange environmental conditions of temperature, pressure, humidity, and radioactivity, it is with difficulty at times that one can trace a signal or even locate a stored bit. It is probable that patterns of trouble shooting behavior which apply to signal-flow type circuits might not apply to storage and pulse type circuits typified by computer logical design. This suggests that behavioral analyses might be required for each total system and the results might reveal fundamental differences in behavioral patterns. If all electronic systems elicited the same general troubleshooting behavioral patterns then there would be a general formularization, but if special systems revealed different patterns then a family of formulas would be created. This outcome should have a profound influence on the selection of the general-purpose or special-purpose teaching machine and the design of the latter.

General-Purpose and Special-Purpose Teaching Machines

Briggs visualized two kinds of teaching machines: verbal or classroom and simulator or maintenance; and he is completely correct in identifying them separately (Briggs, 1959a and Briggs, 1959b). The difficulty in which the teaching machine field finds itself is the absence of a suitable vocabulary with which it can communicate. This matter is important because Briggs' concept must be defined in such a manner that it can be applied to fields other than maintenance training if the concept is what it appears to be. The author identified the general-purpose teachine machine as one by which a variety of different subjects may be taught, as versatile and flexible to satisfy multi-directional objectives (of typical correspondence programs), and the special-purpose teaching machine which included simulators which were fixed-programed so as to treat only one kind of subject matter or by which only one specified subject may be taught (Silvern, 1961a) and Silvern, 1961b). The author also classified general-purpose teaching machines as consisting of visual (manual, mechanical, electromechanical, electro-optical); aural (electrical); aural-visual (electro-optical); and olfactory, gustatory, tactile. Levine and the author further described the general purpose as one which will permit a fixed variety of methods with a nearly unlimited variety of contents; in which methods were equated to psychological principle and contents consisted of subject-matter (Levine and Silvern, 1960 and Levine and Silvern, 1961). Levine said that he understood the general-purpose teaching machine to be one designed for multiple subject matter, in which the displays and types of student responses were universal in nature and applicable to an infinite number of related or unrelated subjects; information stored in the device might be easily removed or inserted (Levine, 1960). Although the controlling mechanism of any general-purpose teaching machine is unique to the device itself, most any content can be geared to be compatible with this mechanism. As far as the device is concerned, he said, it is designed independently of what it will teach. In Levine's analysis, the special-purpose teaching machine was designed so that only one specific body of knowledge is learned. It cannot be used for any other purpose .....certain unique content, requiring special indicators, operations and/or responses, was to be taught. If any feature, be it the method of responding and/or the type of indicator and/or content, etc., is unique, the machine would be considered as special-purpose. To change the content would mean to actually physically redesign the machine itself. Because the design and use is for one specific purpose, these are called special-purpose teaching machines (Levine, 1960).

With these definitions, Briggs' maintenance teaching machine and simulator teaching machine would fall under special-purpose teaching machines and logically this should yield an analysis similar to the one for general-purpose. However, it is at this point that the sparks begin to fly, since there is little agreement on the nouns: simulator, trainer, et al. Perhaps this matter should be deferred for another time, but it is obvious the terms simulator and simulation have gotten out of hand and need clarification if we are to proceed with this analysis.

The writer has been studying the possibility of designing a special-purpose teaching machine driven by a general-purpose digital computer of standard design and configuration—a shelf item, so to speak. Different special-purpose teaching machines driven by the same computer would be the parallel case of the general-purpose teaching machine in groups of, let us say, twenty driven by a central, general-purpose computer as mentioned by Weimer, Ramo, Silvern, and several others and which is under investigation by Coulson and Silberman at System Development Corporation (Silvern, 1961a). The computer control is a common practice in engineering and human factors laboratories where analog and digital simulation is required.

The job analysis and behavioral studies would establish the various knowledge and manipulative activities which are directly, indirectly, or generally related to the end performance objectives—or unrelated to them and therefore confusion-generating. Together with job performance standards, this information should result in selection decisions with respect to the types of teaching machines best suited for the maintenance learning environment. The locale for such a system, which is some years away, would probably be a technical school. With the rapid acceptance of general-purpose digital computers having high-speed, time-sharing capabilities, only the computer input-output coupling, the teaching machines, and the computer program would be needed to add to an existing computer in use for other than learning purposes, thereby reducing capital expenditures.

Those who work with, think about, and write about teaching machine technology often make statements which while general in scope really should be limited to specific areas. Eight such areas of application for teaching machines have been identified as follows (Levine and Silvern, 1960 and Levine and Silvern, 1961):

1. Business and industry.
2. Government (non-military).
3. Military.
4. Public education (K to 12th year).
5. Higher education.
6. Adult and special education.
7. Education and training assistance to foreign countries.
8. Home and family.

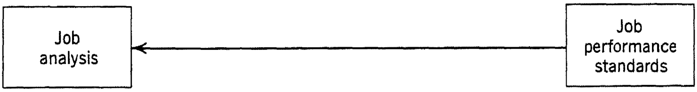
This article deals almost exclusively with military with some small application to business and industry and no reference to any of the others. In this area, the system described can develop quickly due to need. This system concept, however, will not be accepted as rapidly in other areas, as has been pointed out (Silvern, 1961c), due to the unique characteristics of the areas.

Curriculum Development

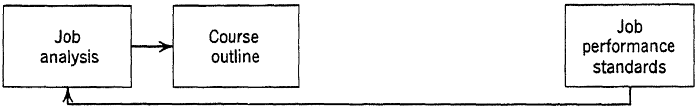
The most exciting part of teaching machine technology is, of course, the development of the lesson itself. Silvern and Levine have described general methods of developing teaching machine lesson plans for general-purpose teaching machines which essentially follow successful lesson planning practices used over a long period of years in technical training environments. The steps generally involve the following:

1. establishing job performance criteria; performance standards dictate the design of the training program and are established by analysis.

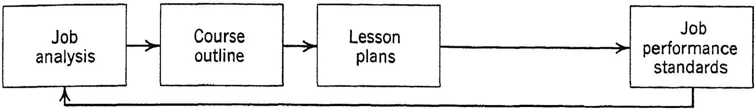
2. producing a job analysis; performance standards are developed into job analysis by the process of synthesis.



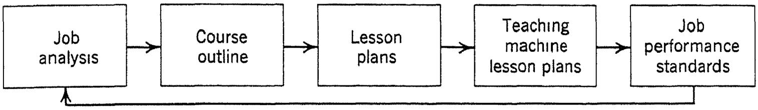
3. creating a course outline from the job analysis by analysis.



4. creating lesson plans next by analysis; consisting of main facts and teaching points.



5. relating human instruction curriculum to machine instruction curriculum.



In developing a teaching machine curriculum for a course which has not been instructed by a human instructor, it is possible to simplify the lesson plan step preceding the teaching machine lesson plan.

This applies to general-purpose teaching machine curriculum development—the classroom situation, usually, as stated by Briggs (1959a and 1959b). In turning to the special-purpose teaching machine, it is evident that behavioral studies, such as those conducted by the Electronics Personnel Research Group at the University of Southern California, the American Institute for Research, and other cited earlier, will contribute heavily to the job performance standards and the job analysis. Generally, however, the main steps in moving from end performance objectives to job analysis, etc., should be unchanged except that the lesson plan will be controlled by the extent of whole-task, part-task philosophies utilized in the task identification. And, of course, the information displays, such as screen projection (visual) and taped voice (aural) now used in the general-purpose teaching machine, will probably appear as visual displays (scope, meter, neon indicator, switch or dial position, screen, et al) in the special-purpose teaching machine. One can think of an application of branching techniques with aural display in which the wrong decision on the special-purpose machine by the learner is not only identified to him, and scored, but also his error is aurally described although he may not be prompted; here too could be an application of the principle of fading. At this point, the writer perceives that he is dreaming as an engineer interested in gadgetry rather than as a behavioral scientist or training specialist armed with experimental evidence justifying these clever feedback schemes!

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Teaching Machines for General and Special Purposes

By STANLEY L. LEVINE and WILLIAM J. KNIGHT
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A teaching machine may be broadly defined as a device the design of which is based on the laws of learning and with which, through interaction between it and a student, the student learns what is prescribed for the machine to teach. This article is particularly concerned with the "interaction" of the machine and the student. How should the student respond to the machine, and how should the machine respond to the student?

The main objective of teaching-machine instruction is to have the student learn what is prescribed for the machine to teach. (This is the essence and sole purpose of any learning situation.) It follows, therefore, that the reaction of student to machine and machine to student should be such as to best facilitate the learning process. In a given learning situation, if the student will learn better by being presented a picture, or a knob setting, or a nut and bolt, this should be the type of presentation he receives, all other things being equal.

By the same token, the response of the student should be selected to optimize learning, all other things being equal. The response he makes might be writing an answer, pressing a button, adjusting a knob, typing an answer, or an infinite number of other responses. The key to the interaction of student and machine lies in the selection of presentations and responses, for a given situation, that best facilitate learning, all other things being equal.

In describing optimum interaction between man and machine above, the phrase "all other things being equal" was repeated several times. Unfortunately, all other things are never equal. Thus, the type of presentation and student response selected should be the result of an evaluation of all factors and their consequences in a learning situation. For example, in teaching a computer card-punch operation, the student might learn better if his response is made on a card-punch rather than a simulated board. The slight expected increase in learning, however, usually does not warrant the cost of an actual card-punch.

TWO TYPES OF TEACHING MACHINES

In many courses, we find that the type of interaction between man and machine is not critically meaningful. A given type of response, such as pressing a multiple choice button or writing an answer, can be used for many different courses. This flexibility enables one machine to teach a multitude of courses. These machines, with a general type of interaction, are called general-purpose teaching machines.

There are learning situations, however, in which the type of man-machine interaction is critical. Other factors make it feasible to use a machine that is capable of teaching only one body of knowledge. This machine has little flexibility, but the learning situation is important enough to forego this capability. These machines, with a special type of interaction, are called special-purpose teaching machines.

General-Purpose Teaching Machines

Many teaching-machine experiments have indicated that the essence of success lies in the information and/or questions and the sequencing of them, not in the machine itself. In part, the reason for this situation, which maximizes the importance of the content, is the fact that most machines provide a versatile, flexible, satisfactory mechanism by which the content can interact with the student. Although the mechanism is important, it is the content and the psychological method that provides the greatest effect on the learner.

The general-purpose teaching machine is one designed for multiple subject matter. The displays and types of student responses are universal in nature and applicable to an infinite number of related or unrelated subjects. Information stored in the device can be easily removed or inserted; the displays usually are slide or film-strip projections or paper appearing at an open window, but audio presentations also can be used. The majority of such machines require one of two types of responses; the multiple choice or the constructed response. Similarities in presentations and responses reduce the difficulty in learning the operation of new machines.

Although the controlling mechanism of any general-purpose teaching machine is unique to the device itself, almost any content can be geared to be compatible with this mechanism. Thus, as far as the device itself is concerned, it is designed independently of what it will teach. In addition, these machines usually are small, light, and portable.

The general-purpose teaching machine has the following five basic functions: input, output, comparison, control, and storage. A block diagram of the machine would look like that shown in Fig. 6-4-1 and would be described as follows:

a. The input unit. This unit accepts the student's responses

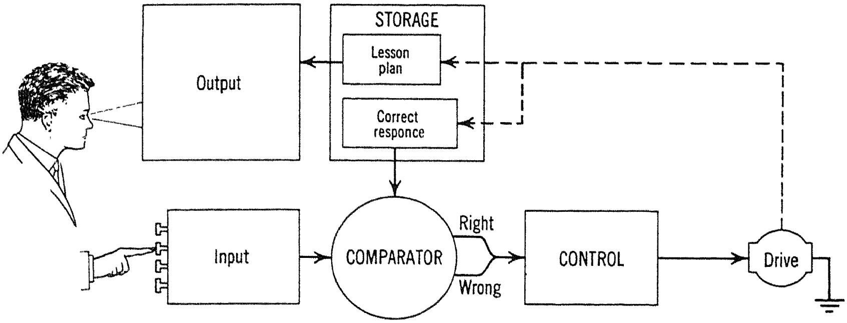

Fig. 6-4-1

and presents them in a form compatible with the requirements of the comparator. The responses may be in the form of buttons to be pressed, written-in answers, or combinations of these.

b. The output unit. This unit presents information and questions, an indication of correct response, and a record of the student's progress. The presentation may be projected on a screen or written on a piece of paper. It may be audio, visual, or audio-visual.

c. The comparator unit. This unit compares the student response input with the correct response from the storage unit and determines if the answer is right or wrong.

d. The control unit. This unit determines the next question, records on a permanent record, and provides reinforcement through lights, etc.

e. The storage unit. This unit stores the lesson plan and the permanent record.

Special-Purpose Teaching Machines

The special-purpose teaching machine is designed so that only one specific body of knowledge can be learned. It cannot be used for any other purpose. One may ask the reason for such an inflexible design. The answer is that certain unique content that requires special indicators, operation, and/or responses must be taught on a special-purpose machine. If any feature, be it the method of responding, and/or the type of indicator, and/or content, etc., is unique, the machine is considered a special-purpose one. The other features may vary.

An example of a special purpose teaching machine is one that teaches radioteletype operation. The probable uniqueness of the input keyboard would designate this as applicable only to the teaching of radioteletype operations.

Usually, special-purpose teaching machines are used when the learning task is important or costly enough to make it financially profitable to go to the expense of manufacturing special machines for instruction. In certain situations a special-purpose machine might replace the actual equipment in a learning situation. In this case, although the teaching machine is expensive, it may very well be a lot less expensive than the equipment that it replaces.

THE FUTURE

As is usually the case, after certain categories are established, the tendency is to join them in special combinations. The future probably will reveal general-purpose machines with special-purpose accessories (for example, a basic general-purpose course in radar fundamentals with accessories for developing certain trouble shooting techniques for a specific radar set). In addition, the growth of simulators probably will benefit by recent developments in teaching-machine technology, and simulators will be developed with teaching-machine capabilities.

SECTION 7. Programing Agencies

This section is concerned with the programing efforts and methods of three different programing organizations. Each article is written from a different point of view and emphasizes the various problem areas encountered by the authors.

The first article examines programed instruction as a training tool for mail-order clerks and telephone-relay adjustors. Focus is placed on an analysis of the conventional teaching methods used for mail-order-clerk training, with a discussion of particular training problems that could be relieved by programed instruction. Details of program construction and problems of program utilization within the framework of the total training system are considered. A cost analysis is presented that estimates the savings resulting from reduced training time for instructors and personnel and from increased task efficiency.

The second article describes research by Schering Corp. directed toward testing the effectiveness of a programed course for pharmaceutical-representative training. Two groups of trainees are compared. One group received conventional classroom lectures that were augmented by a standard textbook. The second group worked at home with a programed textbook that covered the same material. Results indicated that the programed-textbook group obtained superior grades on a company-administered examination of the course material.

The third article describes the principles of mathetics, a system of developing instructional material that differs from both the standard constructed-response programing technique and the multiple-choice-branching technique. The authors provide a detailed description of their method, and explain the special terminology that is used. In addition, an extensive table is presented that compares the mathetical approach to the more well-known, standard programing methods.

Programed Instruction in Business and Industry

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The quickening pace of technological and social change means more attention to learning—the principal process of adaptation to change. In educational and military establishments, great strides have been made toward more efficient learning—particularly in their adoption of teaching machines and programed instruction. Programed instruction also has been applied to industrial and business training, with improved quality and reduced training costs. Programed instruction cuts training costs by reducing the average number of training hours required and by decreasing the requirement for skilled instructors or training supervisors. In addition, the cost of programed instruction, when measured against the potential saving, usually places the training project using this technique well up on the list of priorities given to industrial improvements.

Before getting into case histories that demonstrate the truth of the above statements, we will show how programed instruction provides a bonus by encouraging a rigorous analysis of the job itself, its role in the system, and the cost of training for it, and how, to be assured of a satisfactory outcome, the training director must attend, not only to the obvious *tactics* of reinforcement (the missing words and immediate knowledge of results), but also to the *strategy* of ordering the subject matter in the programed sequence.

MANUAL vs. VERBAL SKILLS

The teaching machine is a rather specialized device reflecting its origin in the laboratory of Dr. B. F. Skinner. According to Dr. Skinner, complex behavior is shaped in an evolutionary manner by refining an organism's emitted behavior in many small steps—a process easily demonstrated in simple organisms such as the pigeon. In humans, Dr. Skinner points to the shaping of verbal behavior, especially the acquisition of vocabulary, as a representative process.

Reflecting his interest in verbal behavior, Dr. Skinner's prototype teaching machine is uniquely adapted to verbal learning, that is, the learning of mathematics, languages, and other skills that require an oral or written response by the student. This means that it also is directly applicable to a large variety of white-collar skills in business and industry. The machine, however, cannot be used to teach manual skills, which are often of particular importance in industry.

For verbal skill, comprehension of the underlying concepts, say of French grammar, is evident through the student's *verbal expression.* For a manual skill, such as aircraft control or the adjustment of telephone relays, comprehension of the underlying concepts, say of aerodynamic response in the first case and mechanical function in the second, is evident in the *manual operations* of the trainee. To exercise a verbal skill, the student needs only a pencil and paper to write out his verbal response or magnetic tape on which to record it. A manual skill, on the other hand, must be exercised on the actual equipment or a reasonable facsimile thereof. Driving, for example, is taught in an automobile. Flying, for the sake of economy and safety, is often taught in aircraft simulators such as the familiar Link Trainer.

Machines for teaching manual skills, therefore, must be more elaborate, specialized, and expensive than the relatively simple teaching machines or programed textbooks that are suited to teaching verbal skills. Machines for teaching manual skills are much more in the spirit of the simulators used by the military. Actually, simulators already embody some of the important characteristics of teaching machines. For example, they give the instructor considerable control over the trainee's behavior, and the instructor can program the input to the trainee and provide appropriate verbal reinforcement. (The pilot in a Link trainer, for example, can be required to "land" many times in succession without having to "take-off.") In addition, malfunctions can be introduced into the equipment by the instructor.

Generally, the instructional program for an aircraft simulator is devised on the spur of the moment by the instructor based on his long training experience and his knowledge of the fledgling pilot's individual training requirements. This procedure often is very effective, but it requires gifted instructors of long experience working with individual trainees. Furthermore, the machine itself seldom measures the necessary performance characteristics or compares such results with criteria for "good" performance—at least not in time to be of maximum use to the student. This defect is not necessarily due to a lack of engineering ingenuity or funds. Rather, it is due to a failure, or the inability, to specify in quantitative, unequivocal terms what constitutes good performance. The determination to develop a programed-instruction sequence with reinforcement at optimum intervals often leads to the necessary definition of criteria and to the development of useful scores and scoring devices.

TACTICS AND STRATEGY IN PROGRAMING

The obvious features of a teaching-machine program (or programed textbook) are the short items, missing words, frequent repetition of key responses, and immediate knowledge of results. These details, however, which largely implement the principle of reinforcement, might be so obvious that they obscure the more diffuse, but equally important, characteristics of an optimum learning sequence. The order in which topics are covered in the sequence is determined by a consideration of such principles of learning as positive and negative transfer, stimulus and response generalization, stimulus discrimination, response differentiation, and span of retention.

Although these principles certainly can be applied without the step-like reinforcement procedures introduced by the Skinner machine, the orderly presentation of stimuli makes the larger strategy easier to implement. One might say that the careful provision for reinforcement provides the motive power for the learning process, whereas the consideration of transfer, retention, etc. determine the route the student or trainee is to take through the subject matter. It is in the planning of this route that the psychologist makes his major contribution to the design of a programed-instruction sequence. This is true whether the skills to be learned are verbal or manual. The route is, however, much more important in training a complex clerical procedure than in the rote learning of nomenclature.

The pitfall that awaits the unsuspecting training director is that, seeing only the blanks in the items, he will fail to appreciate the strategic considerations in the design of the program. Strategy often is more important in an industrial training program than it is in an instructional sequence for academic subject matter. Most academic subjects already follow a more or less traditional curriculum and syllabus. Generally, the pedagogical sequence of the syllabus has been well tried in the classroom and has been reorganized many times to make it more effective. The industrial training director, on the other hand, often must take as his point of departure a procedures manual written by industrial system engineers, and the necessity for reorganizing the content of the manual into a training sequence is apparent.

BUSINESS AND INDUSTRIAL TRAINING

Business and industry present a complete spectrum of skills ranging from manual to verbal. Three applications—one recent, one current, and one projected—serve to demonstrate the application of programed instruction to white-collar group training on predominantly verbal tasks and to blue-collar apprentice training on a manual task. Cases A and B describe programed instruction for package-billing clerks and credit-accounting correspondents. Case C is an analysis of training costs and projected savings in programed instruction for telephone relay adjustors.

Case A—Training Package-Billing Clerks

Several characteristics of the mail-order business make it a good proving ground for programed instruction. It has the large annual turnover characteristic of retail business, and most of the training is concentrated in the fall—just prior to the Christmas rush. Furthermore, many of the tasks to be taught are of a clerical nature and do not require specialized training equipment.

The task chosen for a pilot study at Spiegel, Inc. was package billing—the final clerical operation in the preparation of a package to be mailed to a customer. Spiegel hires about 500 girls for this job each fall. These package billers do the following:

a. Sort out the sales slips.

b. Note the cancellations and substitutions that have been made in filling the order.

c. Total the merchandise price.

d. Calculate a variety of sales and excise taxes, coupon allowance, postage, etc.

Conventional Instruction. Spiegel grouped girls to be trained as package billers in classes of 15 girls each. Up to four new classes were begun each week during the height of the training season. The ten days of this conventional group training were divided between classroom instruction and practice in billing of packages "on the line."

A total of 40 hr were devoted to classroom instruction. During the first several hours in class, the trainees learned to add using the Comptometer. Then they worked through a graded sequence of 75 sample billings. Some of the sample billings introduced new clerical forms or routines; others provided an opportunity for practice. The instructor explained each new point and made occasional blackboard notes. She waited for every trainee to complete each sample billing before moving on to the next one. Short answer tests were given frequently, were scored, and then reviewed in class.

When they had completed 32 hr of classroom instruction, the trainees reported to the billing line and billed sample packages under the surveillance of their instructor. The instructor checked 100 % of their work and tallied the number of packages processed and the number and kind of errors. The systematic collection of these performance data subsequently made it possible to make a very exact quantitative evaluation of the instruction.

After 20 hr "on the line," the group returned to the classroom for 8 hr of additional instruction in Comptometer subtraction and multiplication and "cash" billing. The "cash" training consisted of 55 sample billings. Finally, after one more day of billing "on the line" under 100 % supervision, the girls were given regular work assignments under the usual 4 % quality-control check.

Programed Instruction. As the first step in designing a new course of programed instruction, the consultants took the two-week course for package billers. They did not emerge as very skillful billers, but they did compile a detailed description of the biller's task. Furthermore, they had a chance to look at training from the point of view of the trainee—not the billing expert.

Based on their classroom notes and on established principles of learning, the training sequence was reorganized. In the new instructional sequence, all billing operations that required the same responses were grouped together, and the billers were trained to recognize the cues associated with each of these general response categories. After each general response category was established through practice, the billers were trained to make finer discriminations.

Several techniques were used to expedite the recognition of cues. For example, when a new clerical form was introduced, it contrasted with other forms with which the trainee was already familiar. New symbols, designed to trigger specific clerical routines, were heavily outlined at first. The outline then was gradually diminished over successive exposures until the trainee could detect the cue without this crutch.

As soon as the trainee could recognize all the cues that signify a particular response or clerical procedure, the program was switched to teaching the procedure itself. First, the trainee was required to trace the correct response in the correct location. Then she marked it herself with progressively less assistance from the program. Throughout the program, cue-response combinations previously learned were rehearsed in new contexts to increase the generality of the response. As learning progressed, simple cue-response combinations were put together in more complex sequences leading up to the complete package-billing performance.

Programed Workbooks. Programed workbooks rather than teaching machines were used. Although package billing involves many verbal responses, particularly the writing of numbers, an important part of the job is to write the numbers in the correct spot on hundreds of more or less complex forms. Each of the forms, therefore, must be presented many times and in such a way that the biller actually can write in the results of her computations. Although this requirement conceivably might be met by a very elaborate teaching machine, it is clear that the machine would not be economically feasible.

In all, a series of eleven programed workbooks were used by each trainee. Seven of the books cover the billing procedures themselves, two deal with the Comptometer, one with tax calculations, and one provides refresher training. The pages of the loose-leaf workbooks are of heavy-stock paper. On the left-hand page, and sometimes at the top of the right-hand page, are the clerical forms necessary to introduce a new cue or clerical procedure. In the lower half of the right-hand page is a set of 1-6 instruction cards. The 3 × 5 cards are hinged at the top and overlap like shingles. On the front of each card is a statement about the forms. A blank in the statement indicates to the trainee that she must write out some important missing information on a separate pad. After making her response, the trainee checks it against the correct response, which is printed on the back of the card. Sometimes, instead of writing her answer on the pad, the trainee is directed to make her response on the clerical forms attached to the facing page. Tissue overlays protect the forms for future use.

The Experiment. One hundred and twenty package billing trainees participated in the evaluation in 1960. They were assigned to eight classes of 15 each. Four of the classes received conventional group training. The remaining four classes received their classroom instruction from the programed workbooks. In the experimental classes, the instructor spent her time correcting the quizzes that were integrated with the self-instruction pages, exchanging books, and giving assistance to individual trainees. As might be expected when each trainee sets her own pace, some students were soon one, two, or three books ahead of the other students. To avoid confusion, a numbered card at each desk indicated to the instructor which book the trainee was working on at a given time.

The sixty girls that used the programed-instruction method required an average of 26 classroom hours to learn package billing—a saving of 34% over the 40 hr normally allotted in the conventional group training. (There was an average difference of 10 1/2 hr between the fastest and slowest trainee in each class.) This reduction in classroom hours was achieved without impairing their performance on the job.

Further innovations, which could not be tested during the 1960 training season, might reduce the persistent 3 % error rate in package billing. In 1961, for example, some of the classroom time saved during "cash" training in the second week was reinvested in a review of some infrequent credit operations taught during the first week but not encountered during practice "on the line." It is likely that, without practice or review, these infrequent operations drop out of the trainee's repertoire shortly after they are learned. This would account for a sizeable part of the residual error rate in package billing.

Some Fringe Benefits. A more promising antidote for the residual errors doesn't involve training at all, but it does demonstrate one of the major incidental benefits of programed instruction—methodism. During the training experiment, it was discovered that 40 % of the package-billing errors resulted in "incorrect total postage." Two-thirds of the time, this error was due to a failure by the package billers to recognize the 14 different sales-slip symbols that tell her additional postage must be figured because some of the merchandise ordered by the customer will be sent separately.

In view of the fact that the 14 symbols all meant the same thing to the biller (but not to the back-order clerk), it was suggested that a plus sign be added in the lower right corner of any sales slip that calls for additional postage. This procedure would obviate the need for recognition training on the 14 cues and reduce the "bandwidth" requirement for the package biller. Fortunately, the back-order clerk already was detecting the additional-postage items for her own purposes, although she did not then pass the information along to the package biller; this information was, in a sense, thrown away. Because the back-order clerks customarily have a very low error rate, they can add the plus sign without jeopardizing their own efficiency.

Incentive Plan. The Spiegel incentive program is a key factor in motivation and should be well understood by the employees. If the incentive plan is not well understood, or if it is misunderstood, the effect on production and quality of performance could be quite different from that hoped for by the industrial-engineering department. The complex Spiegel incentive plan is customarily outlined to the employee in a small brochure. As with many other booklets on procedures and benefits, it is doubtful that even a majority of the employees read it thoroughly enough to understand how their errors and production affect their pay envelope. As part of this project, the contents of the Spiegel brochure were remodeled as a teaching-machine program. A formal study was not made of the employees' reaction to the new presentation, but supervisors reacted favorably, and the program was adapted to other jobs.

Some Administrative Pros and Cons. If an hourly rate of $1.50 and 100 % overhead are assumed, the 34 % saving in the conventional allowance of 40 classroom hours per trainee yields a potential saving of $20,400/yr if 500 package billers are trained. This, of course, is an average saving; each trainee proceeds at his own pace and might finish the course before or after the others.

In 1960 the staggered output created problems for the supervisors of the package-billing department. The trainees had to be regrouped for practice "on the line," and the time saved by individual training in the classroom was lost. To avoid this loss, it would be necessary to set up a "training pool" to which new employees would be assigned as soon as they were hired. They would leave the training pool for regular work assignments as soon as they completed the training program.

In addition to a reduction in the average number of classroom hours, programed instruction led to more efficient use of skilled instructors, particularly if the instructor had a clerical assistant to carry on the routine functions of distributing and collecting training materials, correcting quizzes, etc. The availability of the clerk permitted the instructor to devote her full time to helping the less apt trainees. With a clerk, Spiegel instructors could monitor twice the number of trainees they taught when using the conventional group-instruction methods.

Case B—Credit-Accounting Correspondents

In 1961, Spiegel applied programed instruction to another mail-order job: that of the credit-accounting correspondent (CAC). About 45 girls are trained each year to handle mail containing customers' complaints or inquiries about discrepancies, real or fancied, in their account balances. The CAC determines whether or not an accounting error has been made, initiates corrective action if necessary, develops additional information as necessary, and placates the customer.

In conventional training for this job, a supervisor takes about 40 hr to review the procedures manual with a class of 6-8 trainees. Next, the trainees spend eight weeks handling mail under 100 % supervision. Spiegel records show that, throughout this eight-week period, the trainees handle only 2-3 letters per hour—about 15 % of standard for the job—and that they do not approach standard until some months thereafter.

This slow progress may not be entirely a training problem. CAC is not a bonus job, and low motivation might be retarding improvement. CAC trainees who usually handle 2-3 letters per hour increased their output to ten letters an hour for a 1-hr period while they were being monitored by project personnel.

Following conventional instruction, the average error rate at the beginning of the eight-week period under 100% supervision was about 50%. This rate improved to about 20% at the end of the eight weeks, but the reduction in errors could be attributed to the fact that three out of seven trainees were dropped by the end of the period.

As a case for programed instruction, the CAC job is different in many interesting respects from package billing. There is, for example, a more uniform training requirement throughout the year and smaller classes, which means an easier tolerance for the staggered output of individual training. Unlike training for package billing, the CAC job is taught from the procedures manual, and little use is made of cases, so that there is little classroom practice on typical behavior patterns.

The CAC job also has two widely different components. One is the accounting procedure, the other is the simple referral of mail to a variety of other Spiegel activities. The latter component is close to what the psychologist calls paired-associates rote learning and represents the first economic opportunity to use teaching machines for programed instruction at Spiegel.

Case C—Training Telephone Relay Adjustors

A prominent manufacturer of telephone relays produces up to 6,000 relays per day by automatic methods. About 120 men and women are employed to make the final adjustments on the relays. The total manufacturing cost for the average relay is about three dollars. The cost of actually making the relay is about two dollars; the balance of the manufacturing cost, about a dollar per relay, is due to the manual operation of adjustment. Any further reduction in the overall manufacturing cost will have to be achieved through economies in the adjustment operation.

One of the most promising places to look for savings in relay adjustment is in the training of the relay adjustors, about 40 of whom are trained each year. Each new adjustor is trained individually by assignment to an experienced adjustor. He receives a half day of individual lecture and demonstration on the first day and then begins to adjust simple relays under the supervision of his experienced "buddy." Under this system, it takes about three man-months for the average trainee to reach 70% of the production standard for that department. The standard is based on both rate and quality of production. At the end of one year, the average trainee has achieved between 85 and 100% of the production standard.

Training Costs. The cost of training an apprentice relay adjustor before and after programed instruction is shown by the curves in Fig. 7-1-1. To estimate the prospects for savings, we assume that, in this department, one man-day with overhead costs about $40 and that there are about 250 working days per year. The area under each curve represents the value of the production of the trainee during the first year. The area above each curve is the cost of training in terms of lost production.

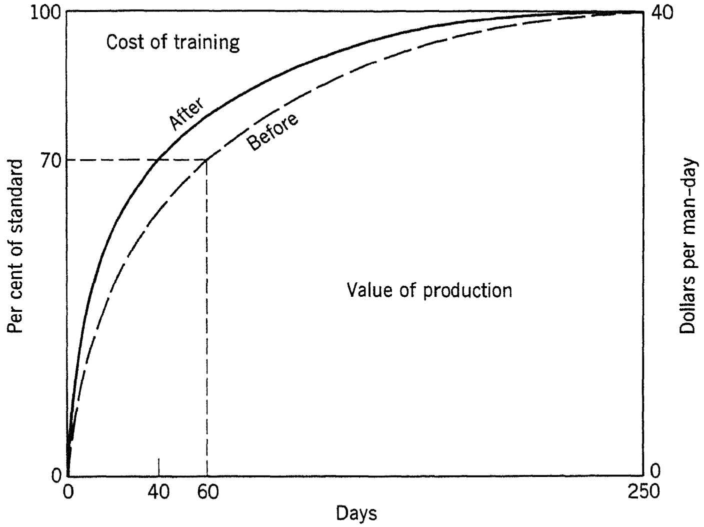

Fig. 7-1-1 Cost of training apprentice relay adjustor before and after programed instruction

Before programed instruction, the cost was $2,000 for one trainee or $80,000 for 40. With programed instruction, the time required to reach 70% of the production standard is reduced by one-third (40 vs. 60 man-days) as shown, and the cost of training is reduced by about 26% or $21,000 for 40 trainees. The estimated one-third saving in the time required to reach 70% of the production standard is based on the results obtained in training the package billers at Spiegel.

To the cost of training an apprentice relay adjustor should be added the cost of supervising the training by the experienced adjustor, which is shown in Fig. 7-1-2. In lieu of more exact data, we make the conservative assumption that the experienced adjustor devotes 50% of his time to his apprentice at the outset of training and that this "nonproductive" supervision decreases in proportion to the growth in the trainee's production.

Before programed instruction, the experienced adjustor sacrificed about 10% of his productivity, equivalent to $1,000 per year,

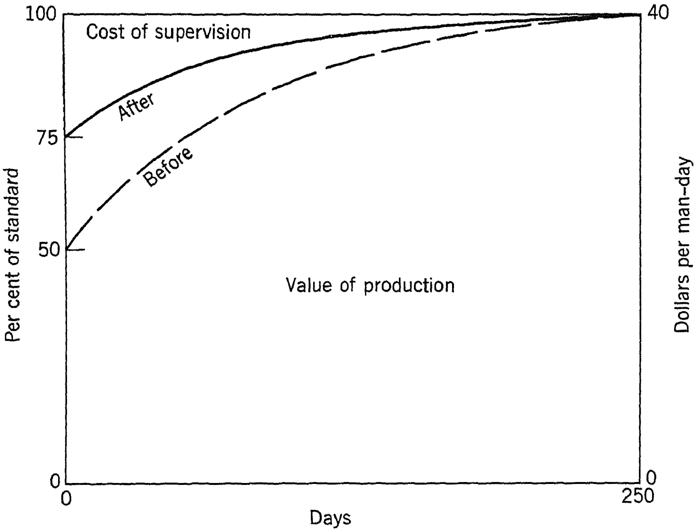

Fig. 7-1-2 Cost of supervising training of relay adjustor before and after programed instruction

to training. Assuming a one-to-one ratio of training "supervisors" to trainees, the total value of production lost from 40 experienced adjustors is about $40,000 per year. Again basing our estimate on the Spiegel study, we assume the requirement for trainee supervision can be cut in half by the introduction of programed instruction. Thus, the potential saving in supervisory time is $20,000. Added to the $21,000 saving in trainee production, this makes a total estimated saving of $41,000 per year (on a current training cost of $120,000—a one-third reduction). The saving is further increased if we assume that more trainees will complete the instruction program.

Even more than package billing, relay adjustment requires manual as opposed to verbal skills. To "act out" his response, the relay adjustor needs a relay, or something like a relay, and the appropriate tools. Because it would be impractical to have the trainee read the successive instructions in the programed sequence, they should be read to him (via magnetic tape) and demonstrated graphically with either still or motion pictures. This requirement for an audio-visual input to the trainee and for a relay simulator on which to perform the necessary manual operations markedly increases the initial cost of programed instruction for manual training over the cost of a teaching machine for verbal learning. There is every reason to believe, however, that the entire cost of the project, including the initial cost of equipping five relay-adjustor training stations, can be recovered in a year or less.

HOW MUCH DOES PROGRAMED INSTRUCTION COST?

Two factors determine the cost of writing a programed-instruction sequence to be substituted for conventional group training of a verbal skill. One factor is the number of items that will constitute the program. The other factor is the time required to prepare each item. The number of classroom hours usually devoted to the subject is the best basis for estimating the number of items that will be required in a verbal-learning program. For example, although few existing programs are that long, most practitioners agree that it will require at least 6,000 items to cover thoroughly a one-semester course on an academic subject such as algebra. If we add 1 hr of homework for each hour of classroom instruction, a conventional course in algebra requires about 150 student-hours. This gives a ratio of about 40 items per student-hour under conventional study methods.

We have already observed that Spiegel customarily allotted 40 classroom hours for the training of billing clerks. The programed sequence that was substituted for the conventional method was about 1,000 items long—a ratio of 25 items to one student-hour of conventional training. This would indicate that the Spiegel program was a little "thinner" than would be expected by projecting the estimate for an academic subject. It should be borne in mind, however, that many items in the package-billing program required time-consuming clerical operations leading to the desired responses.

Several estimates, based on both academic and industrial experience, place the time required for writing the teaching-machine program at 1/2-1 hr per item. This includes the preparation of a first draft, the important trial runs, and final revision of the program. A 1,000-item industrial teaching-machine program would require, therefore, about 750 professional man-hours of program time. Assuming that the direct cost of professional time is $10/hr and that the overhead is 100 %, the minimum cost of the program will be about $15,000. To this must be added the cost of the training materials or apparatus—a factor that can vary widely with the degree of manual training required.

A Case Study in Programed Instruction

By KATHARINE H. HAIN and EDWARD J. HOLDER
Schering Corporation

Schering Corporation has a staff of professional-service representatives that must be trained in the clinical and pharmacological background of the drug products—principally new drugs—that they present to physicians. In today's environment of rapidly widening medical knowledge and therapeutic discoveries, a constant search is necessary to discover new and more efficient training techniques with which to prepare these men to perform their function. To this end, a case study in programed instruction was inaugurated.

The purpose of this study was to compare the effectiveness of a new teaching technique, programed instruction, with that of conventional instruction in the training of Schering representatives. Although much additional experimentation and testing will have to be done before a definitive opinion can be reached as to the real value and place of programed instruction in our teaching curriculum, case reports of initial experiences can be helpful in providing information on what has been done so far, and they might suggest directions for future studies. This case study represents our first step in experimenting with this new technique and, therefore, draws no conclusions but rather presents our tentative impression.

THE INSTRUCTIONAL PROGRAM

The program was designed to cover the clinical and pharmacological background of griseofulvin, an antifungal agent for chronic fungous infections of the skin marketed by Schering Corporation under the trade name of Fulvicin. The programed material was, for all practical purposes, identical with the content of the traditional instruction given previously. The physician who administered the traditional instruction supplied the material included in the program.

We decided to prepare the program for presentation by a programed textbook rather than by a teaching machine. The basis for this decision was threefold: machine presentation of programs has not yet been shown to possess any advantages over textbook presentation for this type of material, the programed-textbook format is considerably less expensive to prepare and administer than the machine format, and a programed textbook is more convenient to use than a machine (a textbook can be mailed and carried around with ease).

An across-the-pages format was used in the programed textbook. The first frame appears at the top of the first page. After the student has written his answer to that question, he looks up the correct answer at the top of the following page, in the upper left. Still at the top of the second page, but now at the upper right, he finds the second frame. As soon as he has written his answer to the second frame, he turns to page three and again finds the correct answer in the upper left.

The student proceeds in this manner until he reaches the end of the book; then he turns back to the beginning and again goes through the book, this time on another series of frames below the first. This across-the-pages format was considered superior to the down-the-page format because the latter results in undesired cueing through the appearance of consecutive frames on the same page, even though the large amount of page turning entailed by the across-the-pages format is admittedly undesirable.

The program was of the constructed-response rather than the multiple-choice variety. The basis for this decision was twofold: one of the fundamental principles of learning theory states that the student must *do* that which he is to learn—the student must learn to *give* the right answers, not merely to recognize them, and multiple-choice items require the student to study incorrect alternatives. (Of course, by studying them, the student learns and retains them to some extent, but he also learns errors that interfere with his later recall of the correct answers.)

PREPARATION OF THE PROGRAM

The instructional program was developed by Basic Systems, Inc., with the assistance of a medical team consisting of physicians at Grace-New Haven Hospital and the Yale University School of Medicine. Members of the Schering Corporation medical and sales training staffs maintained liaison with the programing staff while the program was being prepared. The final program was 783 frames long.

ADMINISTRATION OF THE PROGRAM

To be able to compare the effects of the programed instruction and the conventional instruction, two comparable groups of new representatives were formed.

Group 1 (the control group taught by conventional instruction) consisted of 19 men, 14 of whom had a Bachelors Degree, two of whom had a Masters Degree, and three of whom had no degree but some college training.

Before they convened at the company for a three-week training session, the men were informed that they would be trained and tested on griseofulvin. At the same time, a background brochure, 25 pages long, containing the relevant scientific information was given to them. In addition, sample promotional material and brochures describing the features of the product were made available to them for study. The men were instructed to review the material prior to their arrival at the training session.

During the training session, 4 hr and 45 min of instruction on griseofulvin that involved a combination of lectures and audiovisual presentations was administered by a physician member of the Schering Corporation clinical research staff. After this instruction was completed, the group was told to study their notes and other available materials in preparation for an intensive examination to be given two days later.

Group 2 (the test group taught by programed instruction) consisted of 14 men, nine of whom had a Bachelors Degree, two of whom were Cuban M.D.'s with fair English skills, and three of whom had no degree but some college training. The programed textbooks were received by these men in the mail at home eight to ten days prior to their arrival at the training session. The men were simply told to complete the program and that they would have a test on it early in the training course. The group arrived at the training session on a Sunday night, and they were given the examination on Tuesday morning.

THE RESULTS

The average time for completing the programed text was 10 hr. No classroom instruction on griseofulvin was given Group 2 prior to the examination. The amount of time the men from the group receiving conventional instruction spent preparing for the examination was not determined, but this group spent 4 hr 45 min in class.

The examinations given the control and the test groups were similar but not identical because the two groups were not tested at the same time. The control group was examined in November and the test group in May. The examinations were purposely made harder and more comprehensive than those ordinarily given to a class of new representatives so as to thoroughly challenge the programed-instruction method. The examinations asked for a knowledge of a great deal more factual material than is required of new men who have just started training and who will continue to be trained in the field for many weeks following their classroom instruction at the home office.

The mean grade for the control group who received the conventional instruction was 60.1. The mean grade for the test group who received programed instruction was 91.9. The difference between the two means is significant by the t-test beyond the 0.01 confidence level.

Discussions were held with all members of the group taught by programed instruction. Their reaction to programed instruction was unanimously positive. In response to a course-evaluation questionnaire, all members of the class said that they learned more with programed instruction than with the traditional teaching methods used in teaching them about other products. One man said that the program was too detailed, and one man said that it was not detailed enough. Two men considered it less interesting than the lectures and discussions on other products.

On the basis of these results, our initial impression is that programed instruction gives promise of providing a new and useful teaching technique that could increase the learning efficiency of our professional service representatives and thus improve their training. This technique also gives promise of permitting reduction in our classroom teaching time and allowing more efficient and economical utilization of our professional training personnel.

The Mathetical Design of Effective Lessons

By D. F. PENNINGTON and C. W. SLACK
TOR Education, Incorporated

The purpose of this article is to introduce the reader to the mathetical design of lessons and to mathetics as a method of lesson construction. Mathetics has a number of advantages over other methods—linear and branch programing—because it is more systematic and less restricted to special formats.

As a technology, mathetics derives in detail from basic research in reinforcement theory with lower animals. In its application, it is assumed that man is at least an animal, and this assumption is carried through to the level of production and design details. One conclusion of mathetics is that the best and least expensive way to teach the human animal is to follow closely all that we now know about instilling and sustaining behavior in the lower animals. Through the recognition that he is at least an animal, man is better enabled to distinguish within him that which is truly human and to direct his behavior toward human goals.

One of the very best (and most difficult) initial tests of any technology is in industrial situations because real cost factors directly determine usage and eventual acceptance. Because mathetics uses inexpensive task-simulators rather than teaching machines, does not make use of subject-matter experts to write frames, and does not test lessons until after completion, the cost of preparing lessons is lowered.

CHARACTERISTICS OF THE METHOD

A distinguishing characteristic of the mathetical approach lies in the method for producing the lessons. The result of an original approach based on reinforcement theory rather than a combination of existing techniques, mathetics satisfied the following two criteria characteristic of a true technology:

a. Reliability. Two mathetical teams working independently on the same educational objective (prescription) will produce similar lesson materials, and two matheticists analysing the same task will generate similar prescriptions.

b. Validity. The behavior contained in the prescription can be instilled into all members of the designated population; the prescription depicts the job or educational requirements accurately, provided that they can be behaviorally defined.

As stated previously, an advantage of mathetics is that task simulators are used rather than standard teaching machines. This permits mathetics to teach many kinds of behavior rather than just verbal and written behavior. Mathetics uses a transactional approach in which the trainee actually performs all the operations that will be required of him—he learns by doing. The behavior to be instilled into the trainee can be derived from existing training materials or from a subject-matter expert where good materials are not available. In any case, the behavior to be instilled into the trainee is prescribed in detail in advance and then systematically established in the repertoire in a manner that depends on the type of behavior involved.

Sequences ("chains") in which each response sets up a unique stimulus "state of affairs" are taught backwards. Thus, a salesman would be taught the "close" of a sale first, a machinist the finishing procedure first, and a bank-teller trainee the close and balance of his cage first. In this manner, the lesson establishes the goal firmly in the repertoire of the student or trainee. This procedure corresponds to the food pan in animal work. Once the human knows "where he is going", each step in the chain becomes a reinforcing stimulus by connection with the final state of affairs.

Notice in the example of Fig. 7-3-1 that the first thing we teach is the last thing that a person reading a resistor does, namely, the reading of the tolerance band and the "plus-or-minus" procedure. Lessons produced this way can greatly reduce the bulk of material required.

In addition, with each exercise the trainee does more and more on his own until, at the end, he is performing the whole operation on his own. Also, at each point in the sequence he sees concrete evidence of his increasing knowledge and skill—he knows he can do more now than last time on his own. The speed, accuracy, and high motivation resulting from this approach are unequaled by other methods.

All discriminations ("multiples") are brought to strength simultaneously. Thus, a code or a language that involves large multiple discriminations is taught all at once. It can be shown that any other way of teaching greatly increases the time and decreases retention. If, for example, we want to teach an animal to distinguish between two lights, we present both to the animal at the same time. Thus, in teaching a salesman to meet customer objections, such objections and their appropriate responses would be taught at the same time and brought to strength by repetition and decreasing use of intermediaries—all at the same time. For instance, we teach an entire color code in one "frame" (see Fig. 7-3-2). To teach the code color by color in either linear or branching fashion, would require many more frames.

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4. The FOURTH COLOR BAND gives the PERCENT OF ERROR tolerance in the resistance rating. The FOURTH BAND can have one of three colors; each COLOR stands for a PERCENT. Learn them.

Accuracy with 5% of rating—FOURTH BAND is GOLD

Accuracy within 10%—FOURTH BAND is SILVER (silver-dime)

Accuracy within 20%—FOURTH BAND is BLACK or MISSING

NO ANSWER REQUIRED

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5. What is the tolerance percentage of a resistor if it is:

	% Tolerance
(a) 400 ohms and the 4th band is MISSING?	± 20%
(b) 300 ohms and the 4th band is SILVER?	± %
(c) 200 ohms and the 4th band is GOLD?	± %
(d) 100 ohms and the 4th band is BLACK?	± %

(a) 20% (b) 10% (c) 5% (d) 20%

Fig. 7-3-1 Two exercises selected from a mathetical lesson that teaches all the behavior involved in reading and electrical resistor. The lesson is twenty exercises long

Generalizations are taught with what looks like, superficially, old-fashioned mnemonics. There is a great difference however. In teaching a generalization, we use an already existing response in the repertoire of the animal that is, also, a stimulus for the new response that we wish to establish. We thus create a small chain the center of which, the mnemonic, will tend to drop out with use (the animal always tends to shorten chains over time). When the mnemonic drops out, we are left with the desired stimulus-response (*S*-*R*) relationship. In Fig. 7-3-2, we can see that each color-number generalization is taught in minimum time with its own mnemonic bridge. Here we are putting competing behavior to work for us by strengthening a particular competing response that is also a strong stimulus for the desired response.

COMPARISON OF MATHETICS WITH OTHER METHODS

An analysis of the mathetical approach (see Table 7-3-1) shows that, even though it includes those parts of other methods that are compatible with the laws of animal behavior, it must be counted as a separate procedure. A distinguishing characteristic of other methods is their treatment of format as a policy matter

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7. Each of the FIRST THREE COLOR BANDS can have one of 10 colors. Read through this list twice. Learn the NUMBER for which each COLOR stands

. a FIVE dollar bill is GREEN
. ONE BROWN penny
. a WHITE cat has NINE lives
. SEVEN PURPLE seas
. a BLUE tail fly has SIX legs
. ZERO: BLACK nothingness
. a RED heart has TWO parts
. THREE ORANGES
. a FOUR legged YELLOW dog
. an EIGHTY year old man has GRAY hair

NO WRITTEN ANSWER REQUIRED

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8. List the number for which each COLOR stands:

RED ____ (heart)	WHITE ____ (cat)	PURPLE ____ (seas)	BROWN ____ (penny)	BLACK ____ (nothingness)
GREEN ____ (bill)	GRAY ____ (hair)	BLUE ____ (tail fly)	ORANGE ____ (oranges)	YELLOW ____ (dog)

LEARN ANY YOU MISS BEFORE GOING TO NEXT EXERCISE

Red 2	White 9	Purple 7	Brown 1	Black 0
Green 5	Gray 8	Blue 6	Orange 3	Yellow 4

9. List the NUMBER for which each color stands:

BLACK ____	BROWN ____	YELLOW ____	GRAY ____	GREEN ____
WHITE ____	PURPLE ____	RED ____	ORANGE ____	BLUE ____

Black 0	Brown 1	Yellow 4	Gray 8	Green 5
White 9	Purple 7	Red 2	Orange 3	Blue 6

Fig. 7-3-2 Three exercises selected from the same mathetical lesson as that of Fig. 7-2-1

to be set *a priori*. This format is assumed to include the following:

a. The ways of presenting the material once it has been programed.

b. The kinds of responses (multiple-choice or constructed) that are allowed the student.

c. The consequences of those responses to which the programer is limited.

Partisans of the linear and branching approach differ on the best form for presenting a reinforcer and the kind of schedule on which it should be delivered. Both assume that outside indicia

Table 7-3-1 Comparison of Linear, Branching and Mathetical Approaches to Lesson Preparation

Elements of lesson preparation	Approaches		
	Linear	Branching	Mathetical
Presentation format	Decided in advance	Decided in advance	Decided near end of lesson preparation
Machine presentation	Frame display with or without separate answer tape	Frame display with multiple-choice buttons	Task simulators, usually of cardboard or plastic
Book presentation	Linear program	"Scrambled" program	Varies with type of behavior involved
Frame	Fixed frame smaller than one page	Fixed frame of full-page size	Varies
Amount of information given in each step	Small	Large	As large as possible
Number of steps in lesson	Large	Smaller	As small as possible
Errors allowed by student or trainee	In theory, none; in practice, 5% (some individualization added)	One less than number of choices given	Some errors built in to focus attention (some test items for individualization)
Try-out testing	Every few frames (written and then tried out)	Varies	Only after entire lesson completed
Content	Determined by programer	Determined by programer	Determined by stimulus-response analysis of subject matter
Unit of measure	The frame	The frame	The operant (amount of behavior that is changed by lesson)
Response	Constructed or written	Multiple choice	Combined task simulation and written or other construction

Table 7-3-1 (Continued)

Elements of lesson preparation	Approaches		
	Linear	Branching	Mathetical
Programers	Should be subject-matter expert	Should be subject-matter expert	Need not be subject-matter expert
Reinforcers	Being right (being allowed to go on to next frame on fixed-ratio of one)	Knowledge of results (being right or wrong on variable ratio)	In general: task completion and rate of increase. In particular: each stimulus in prescription becomes reinforcing stimulus connected to final "state of affairs" through chain. Student is almost always correct
Theoretical basis	Immediate positive reinforcement	Socratic method	Immediate positive reinforcement plus all other aspects of reinforcement theory: theory: chaining, discriminations, generalizations, scheduling, etc.

of whether the student is "right" constitute the best reinforcer. Linear programers try to put the student on a fixed ratio of being right on each frame, whereas the branching programers use a variable ratio that allows the student to be wrong a certain portion of the time.

The mathetical approach does not assume that outside indicia are the best reinforcers even when delivered immediately by a machine. Actually, students will work to be right (or to find out whether or not they are right) only to the extent that they have been deprived, in the past, of such information. After a while "immediate knowledge of results" looses its reinforcing strength because this strength derives only from our present educational methods, which deprive the student of success in this form.

Initially, because both linear and branch programs look like tests, the student is gratified to get the answers right, but he may fail to complete the program if left on his own. From a strictly behavioral point of view, these programs effectively maintain the behavior of reading and writing as long as the state of deprivation of success lasts; the teaching is incidental, and the student is left to devise his own method for learning the material.

In the application of mathetics, each stimulus "state of affairs" in the final behavior is developed into a reinforcing stimulus through association with the final state of affairs. Outside information as to whether or not the response is correct is given only in the beginning to reassure the student or trainee and to give him confidence in his own correct behavior.

MATHETICAL LESSON PREPARATION

Mathetics makes use of an extensive function analysis and prescription in which the task or subject matter to be instilled is prescribed in terms of animal behavior (stimulus-response units called operants).

Phase 1. Function Analysis

First, the educational and training objectives are defined in rather general terms according to an analysis of the real cost factors and other educational objectives. A reduction in training time or saving in personnel is not the only, or even the primary, objective. All self-instructional lessons and programs reduce training time and ease the load on personnel, but these, by themselves, are seldom the major cost factors, even in industry. To give an example—one of the major cost factors in the training of department-store employees is not training time, or even the load on personnel, but training space: classroom space and other space devoted to training. This factor is second only to the cost of operational reliability, that is, to mistakes made by trainees—although, in the department-store business, it is not always the new employee who makes the most mistakes.

In many other industries, "drop outs" in training are a major cost factor. In some industrial situations, the real cost factor is the effective flow of trainees into operations so that the time of trained supervisory personnel is used to its greatest efficiency. In each situation a well-designed mathetical lesson would be designed and installed to reduce such real cost factors, which vary between and within industries and situations.

A subject-matter expert is consulted prior to, or in conjunction with, the collection of data to define more specifically the task or educational content and the student or trainee. The subject matter expert *does not* advise the matheticist as the *method* of teaching—he advises only as to the elements essential to a mastery of the task being taught.

Data collection involves more than just a detailed description of the elements traditionally related to a task. The actual elements essential to a mastery of the task or content are sought, and the usefulness of an element in the performance of a function, as opposed to the learning of that function, is determined. The inclusion of elements for purely traditional reasons is discovered and the economy of an element in terms of frequency, importance, etc., is evaluated.

Phase 2: Prescription of Behavior

The "prescription" is a convenient and standardized way of representing the behavior to be taught. The basic unit of the prescription is the "operant," which consists of a single element of the behavior (R) plus its stimulus condition (S). Hence the operant takes the form of a stimulus-response relationship (S-R), a series of which can exist in virtually any combination. Actually, any lesson is represented by both a "synthetic" (practice) and an "analytic" (theory) prescription, each of which serves a distinctive and essential purpose.

The Synthetic Prescription. The final synthetic prescription is most commonly derived by a series of approximations directed toward a synthesis of the behavior expressed in optimally-sized units or operants. The *first* prescription is usually the most detailed because any question as to operant size is resolved by selecting the smaller, that is, if there is indecision as to whether a bit of behavior should be represented by one unit or two, the latter is chosen. This assures that all steps integral to the final operation are considered.

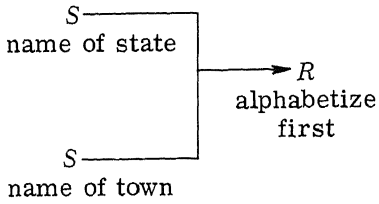
Basically, there are three kinds of operant arrangements: sequences ("chains"), discriminations ("multiples"), and generalizations. A "chain" of operants is derived from behavior consisting of sequentially-ordered units, as in

$S \longrightarrow$	R	·	$S \longrightarrow$	R	·	$S \longrightarrow$	R
Skinner Box	Pull Chain		Light on	Press Lever		Food Appears	Eat Food

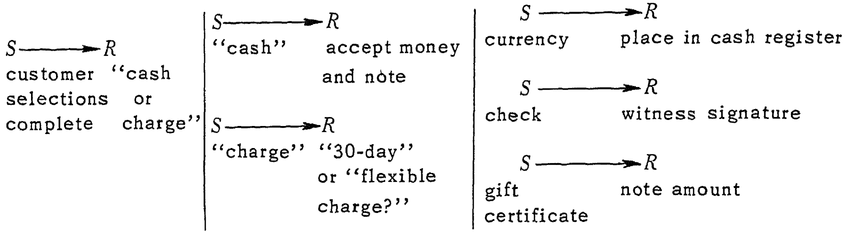
A "multiple" represents a series of contingencies with no essential order, as in

$S \longrightarrow$	R
red light	turn right
$S \longrightarrow$	R
blue light	turn left
$S \longrightarrow$	R
white light	remain

A "generalization" represents several conditions requiring the same response, as in



Usually, some combination of the three is obtained, as in



The *second* approximation to the final prescription derives from a refinement of the first, in which operants are collapsed so that any error is on the side of operants that are too large. (Note that any error away from optimally-sized units can be spotted easily in empirical test if an operant is too large but not if it is too small.) The final prescription contains all elements of the original but in a relatively condensed version. Thus, the synthetic prescription can appear as a complex of operations, each composed of a series of operants and combining to yield a rather mechanical picture of the total behavior to be taught. The second type of prescription is derived from an analysis of the operations so depicted.

The Analytic Prescription. The operations of the final synthetic prescription are examined for common properties and collapsed into a complex of schematics. On the basis of the schema, a single "Archetype" problem (real or unreal) is sought that will serve as a basic model for all cases; i.e., one that involves all distinguishable operations. If such a problem cannot be found, the best compromise is used—one that invites greater generalization but may be expressed in simple terms (a "paradigm" problem). The paradigm problem (or problems) is then prescribed and subjected to the same subsequent treatment as the synthetic material.

Phase 3: Characterization of Behavior and Lesson Plan

Characterization involves extensive consideration of each operant comprising the final synthetic prescription, with particular regard to the following two sources of difficulty in teaching:

1. **Discrimination Difficulties.** It is recognized that a basic quest in learning concerns the stimulus situation appropriate to a response (as opposed to the response itself), that is, it is easily demonstrable that virtually (perhaps literally) any segment of behavior necessary to mastery of a practical task is already in the repertory of the learner. The crucial task is that of relating the behavior to its appropriate stimulus context. (A little reflection on the problems of learning to speak a foreign language is illustrative.) Thus, of primary concern are the discrimination difficulties already learned or, more succinctly, the "incorrect" stimuli most likely to elicit a particular response. A recognition of such competing tendencies are systematically noted for later consideration and special treatment.
2. **Generalization Difficulties.** Obviously, any stimulus situation, when verbally described, can be only a symbolic approximation to reality. We are here interested in the degree to which a given stimulus, taught in symbolic fashion, will generalize to all situations in which the response is approximate. Again, each operant is examined for probability of generalization failure and appropriate notation is made for later treatment.

The lesson plan incorporates all elements heretofore developed and outlines the actual teaching sequence. The first exercise strengthens the last operant (for reasons that encompass a large bulk of reinforcement theory and will not be discussed here). This operant and each successive (or, more literally, successively preceding) one is taught in three exercises, the first of which is described as a "demonstration," the second as a "prompt," and the third as a "release." Thus, a simple, three-unit chain and its lesson plan appears as

$$S_0 \rightarrow R_1 \quad \cdot \quad S_1 \rightarrow R_2 \quad \cdot \quad S_2 \rightarrow R_3$$

Exercise	Demonstrate		Prompt		Release	
1	S_2	R_3				
2	S_1	R_2	S_2	R_3		
3	S_0	R_1	S_1	R_2	S_2	R_3
4			S_0	R_1	S_1	R_2
5					S_0	R_1

It can be observed that Exercise 1 serves to demonstrate the last operant; Exercise 2, to demonstrate the immediately prior operant and prompt the last one; etc. Parenthetically, there are always two more exercises than operants.

Phase 4: Exercise Writing

The lesson plan indicates that each operant is strengthened in three exercises—but in a differential manner.

The Demonstration. An operant is initially introduced in a very precise way. In addition to the reinforcement afforded by successful task completion, it is recognized that proper stimulus control is an integral part of the teaching process. For this reason, the following several aspects of the stimulus are routinely treated:

a. The S^d is the actual stimulus situation that is to produce the response of a given operant. Obviously, such a stimulus situation usually cannot be presented per se. Rather, some symbolic representation (usually verbal) must be used.

b. The S^a, literally the "attention" stimulus, locates for the student the S^d (i.e., points out the S^d in such a way that it (the S^d) cannot be overlooked or confused), and the S^a identifies the essential characteristics of the S^d so that it can be generalized and delimited appropriately. Both aspects of the S^a must be present in every "demonstration" of an operant.

c. The S^v normally takes the form of a verbal instruction phrased in such a way that the response is forced (the student cannot reasonably make an error) in the presence of the S^a.

The Prompt. Each operant is prompted in the exercise following the one in which it was demonstrated. This is accomplished by means of a "residual" S^v (the $\bar{S}^v$), which provides the essential elements of the S^v, again in the presence of the most distinguishing characteristic(s) of the S^a.

The Release. In the exercise following its prompting, each operant is strengthened by a repetition elicited by the preceding response. (In a chain, each response produces the stimulus of the next operant.) It can be noted that, with the exceptions of the first two and the last two, each release strengthens three operants. Thus, in the sample lesson plan presented, Exercise 3 serves to demonstrate the operant S_0-R_1, to prompt S_1-R_2 and to release S_2-R_3. (The release of the last operant in a chain can be elicited by the simple verbal instruction, "Now complete the operation," following the prompting of the preceding operant.)

Phase 5: Task Simulation and Format Design

At this point (and not until this point) consideration is given to the form of the final lessons. Normally, the exercises are readily suggestive of a gross format (a programed book, teaching machine, kit, etc.). Anyone who insists on a particular format in advance should be cautioned that such a format might not be the most efficient one for his particular task. Three primary considerations are paramount here:

a. The probability of generalization to the actual performance situation.

b. Comparative efficiences of fitting various formats to the exercises (relevant factors include length of exercises, kind of behavior (whether primarily verbal or motor), types of symbolization employed, nature of the operant components, space and facilities available to the students, etc.).

c. Production (fabrication) feasibility and costs.

Again, it must be emphasized that any precise restrictions imposed by the client are often to his disadvantage because the most appropriate format is seldom if ever discernible prior to the completion of all preceding phases.

Phase 6: Editing and Evaluation

The writing of the exercises as described assures that all technical components are introduced. It does not emphasize efficiency of presentation of these components, which is one of the functions of editing and evaluation. Editing and evaluation is responsible for three operations: rewrite and layout editing, copy-editing, and try-out editing.

The rewrite and layout editor is concerned solely with the communicability of the language and the related illustrations of a lesson. Though trained to recognize and to know the function of the components, the person responsible for rewriting and layout editing never concerns himself with their accuracy or their adequacy—only with whether they are properly communicated to the trainee.

The copy editor assures grammatical correctness, clarity, and consistency of language and format. He approaches the lesson from the trainee's point of view. He must return the lesson to the rewrite and layout editor for approval of any changes. The lesson then is reviewed by an editor to verify that the mathetical components have not been distorted or deleted in the preceding operations.

Try-out editing involves testing a lesson with a selected "subject trainee" who most nearly conforms to, or is actually of, the trainee population. It is within this step that all aspects of the lesson are evaluated—especially the mathetical components. Special procedures are applied whereby each aspect of the lesson can be readily identified and appraised by the try-out editor throughout the testing session.

It should be noted that not only after the try-out operation, but at any point, a lesson can be returned for revision to an earlier stage of development if such is deemed necessary. The matheticist, to exercise maximum control, deliberately builds into his lessons possible sources of error; therefore, lessons are redesigned, re-edited, and re-evaluated as many times as necessary to achieve the criterion product.

Phase 7: Installation

The installation procedures of a mathetical lesson, in large part, determine its success in business, industry, education, etc. Though different in its obvious form, a lesson, like any new "equipment," must be installed properly, used properly, tested properly, and given proper servicing. Thus, the proper installation steps must be followed closely to achieve the best results.

* * *

For most of the ideas contained in this article, credit is given to Gilbert, T. F. (1962) Mathetics, the technology of education, Journal of Mathetics, *Vol. 1, No. 1. The authors, however, assume full responsibility for the adequacy of exposition.*

Appendices

APPENDIX A: THE FIRST 10 FRAMES (OUT OF 719) OF THE 7070 PROGRAM PREPARED BY IBM

Frame 1

The 7070 is a data processing system. To prepare a payroll, to maintain an inventory, or to perform other accounting applications, a customer can use the 7070 data ______________
____

PROCESSING
SYSTEM

Frame 2

All data processing systems require some type of input unit or units. In order to put information into the 7070
____
______________, an ______________
unit is required.

DATA PROCESSING
SYSTEM INPUT

Frame 3

In addition to one or more input units all data processing systems require some sort of processing unit or units to operate on the input data. The 7070 has several ______________________________
units to process input data.

PROCESSING

Frame 4

Data are put into the 7070 by means of an ______________________ unit. The information (data) is then operated upon by several ______________________
______________.

INPUT
PROCESSING
UNITS

Frame 5

All data processing systems must also have output units to write out information in a usable form. A mechanical printer is an example of an
______________________________ unit.

OUTPUT

Frame 6

The 7070 data processing system can perform various accounting applications through the use of its various basic units. These basic units consist of________________units, ________________units, and ________________units.

INPUT
PROCESSING
OUTPUT

Frame 7

The 7070________________ ________________ can have various types of input units. The 7500 Card Reader is one of the ________ units for the 7070 system. To read card information into the 7070 we use the________________ ________________.

DATA
PROCESSING SYSTEM
INPUT
7500 CARD
READER

Frame 8

To read punched card information into the 7070, we use a____________ Card Reader.

7500

Frame 9

The 7500________________ unit reads card at the rate of 500 cards per minute (C.P.M.). Since a maximum of three 7500 units can be used with the 7070 system, a total of____________ cards per minute (C.P.M.) can be read into the 7070.

CARD READER
1500

Frame 10

A maximum of three__________Card Readers can be used with the 7070 system. Each Card Reader can read cards at the rate of________________C.P.M. It will help you to recall this by remembering that the__________Card Reader unit handles________________C.P.M.

7500
500
7500
500

APPENDIX B: SAMPLE OF 10 ITEMS FROM AN 88-ITEM ACHIEVEMENT EXAMINATION PREPARED BY IBM

5. Identify which of the following units use the magnetic drum for buffer storage.

a. 7400 Printer
b. 7501 Console Card Reader
c. 7550 Card Punch
d. 7500 Card Reader
e. 7900 Inquiry Station

12. What is the maximum number of typewriters in the 7070 system?

20. Draw a block diagram of the complete 7070 system. Label each block with name and number. Draw arrows to indicate the data flow paths.

23. The following bit positions make up a word in storage. What is the word?

03 16 01 16 06 16 23 06 23 26 02

50. Give the field defined digits and their sign for the instruction words below:

Data Words:
0800 = −8274316721
1234 = +2364510793

Instruction Words:	Sign	Digits
+14 00 09 0800		
−14 01 00 1000		
+14 00 02 1243		
−23 01 36 1443		

Index Word:
0001 = 0002000700

52. What is the effective address portion for each of the following instructions:

Given:
IW 01 = −0074532640
IW 02 = +0033642751

Instruction Words:	Effective address portion
A. +14 01 09 0700	
B. +13 02 27 0800	
C. −14 01 09 0200	
D. −50 02 69 8420	
E. −13 01 27 0642	

59. In a phrase or sentence, give the function of the Instruction Cycle.

69. What registers (10 digits and sign) are used when reading from a 7500 Card Reader?

79. Draw a flow chart of the program step showing the various cycles.

88. Draw a block diagram of the information, arithmetic, and distributor buses showing their associated registers capable of handling 10 digits and a sign. Indicate all connections.

APPENDIX C: RESPONSES OF AN EXPERIMENTAL GROUP (n = 70) TO AN IBM STUDENT QUESTIONNAIRE

Compared to the regular classroom method used in other IBM courses you have taken:

1. How well has the programed instruction (PI) method taught you the material covered?

☐ PI much less effective than regular classroom method

☐ PI somewhat less effective than regular classroom method

☐ PI about the same as regular classroom method

21% ☐ PI somewhat more effective than regular classroom method

79% ☐ PI much more effective than regular classroom method

2. How do you like the programed instruction (PI) method?

3% ☐ Like PI much less than regular classroom method

3% ☐ Like PI somewhat less than regular classroom method

7% ☐ Like PI and regular classroom method about the same

24% ☐ Like PI somewhat more than regular classroom method

63% ☐ Like PI much more than regular classroom method

3. How difficult was it to learn using the programed instruction (PI) method?

☐ PI much more difficult than regular classroom method

☐ PI somewhat more difficult than regular classroom method

7% ☐ No difference in difficulty between regular classroom method and PI

31% ☐ PI somewhat less difficult than regular classroom method

62% ☐ PI much less difficult than regular classroom method

4. How much home study does the programed instruction (PI) method require?

3% ☐ PI requires much more home study than regular classroom method

13% ☐ PI requires somewhat more home study than regular classroom method

24% ☐ PI and regular classroom method about the same

36% ☐ PI requires somewhat less home study than regular classroom method

24% ☐ PI requires much less home study than regular classroom method

5. In future IBM courses you may take, would you like to see the programed instruction (PI) method used in place of the regular classroom method?

☐ Strongly object to using PI in place of regular classroom method

13% ☐ Would have some objections using PI in place of regular classroom method

4% ☐ Don't care which method is used

37% ☐ Have some preference for using PI in place of regular classroom method

46% ☐ Strongly prefer using PI in place of regular classroom method

6. Was there anything about programed instruction that you particularly liked?

Learning of material much easier. Information presented in a very clear manner.

Student can proceed at his own learning rate.

Instead of listening and note taking, the act of actually reading and answering keeps one's attention more alert and much less apt to miss anything.

Step-by-step building up of principles with ideas repeatedly, constantly when important.

Covered much more material than the classroom lecture in the same time period could have covered effectively.

7. Was there anything about programed instruction that you particularly disliked?

Too much turning of paper. A machine would be nicer. The amount of writing and the repetition.

Too much can become somewhat boring. I feel method should be used with moderation along with conventional classroom techniques.

You should not be times. Time allotted for each unit seems to be geared for very rapid readers.

Material as written is not too well adapted for review work since it requires so much time to re-read.

Some sections were much too basic. The PI course should be geared to the individual student. This is one advantage of PI . . . where in the lecture the instruction would have to start his lecture at the lowest point.

8. Use the space below to make any other comments you wish to make regarding programed instruction.

At the end I would like to see a summary in paragraph form or block form.

Use of this should be continued, but not in entirety. It should be broken up with classroom instruction.

Program should be expanded to cover more of course. On the whole, I believe this is the best method of learning I have ever seen.

This section should be sent into the field for C.E.'s to complete before they come to Poughkeepsie.

A good method but time should be taken for some cannot read as fast as others.

APPENDIX D: SAMPLE EDUCATION AND EXPERIENCE QUESTIONNAIRE

Prepared by IBM

Last Name	First Name	Middle Initial	Man Number	Office

Check Whether DPD ☐ WTC ☐ Other________________ Date of Birth __________

EDUCATION

	Check if Graduated	Major Subject (If any)	Indicate Length of Time Attended
High School (s)	☐	__________	Years ______ Mos. ___
Technical School (s)	☐	__________	Years ______ Mos. ___
Armed Forces Tech. School (s)	☐	__________	Years ______ Mos. ___
College (s)	☐	__________	Years ______ Mos. ___

TECHNICAL EXPERIENCE

Enter total time as IBM DP CE: Yrs. ______ Mos. ____

	Check Whether			Type of Job Held	Type of Computer or Equipment	Time on the Job
	None	IBM	Pre-IBM			
Unit Record Equipment Experience	☐	☐	☐	______		Yrs. ______ Mos. ______
		☐	☐	______		Yrs. ______ Mos. ______
		☐	☐	______		Yrs. ______ Mos. ______
Data Processing Systems (computer) Experience	☐	☐	☐	______	______	Yrs. ______ Mos. ______
		☐	☐	______	______	Yrs. ______ Mos. ______
		☐	☐	______	______	Yrs. ______ Mos. ______
Other Technical Experience (TE, ET, Electronics, etc.	☐	☐	☐	______	______	Yrs. ______ Mos. ______
		☐	☐	______	______	Yrs. ______ Mos. ______
		☐	☐	______	______	Yrs. ______ Mos. ______

APPENDIX E: THE FIRST 50 FRAMES OF A PROGRAM IN LIBRARY USAGE FOR JUNIOR HIGH SCHOOL

*Prepared by Automated Teaching Systems, Inc.**

1

Books in a library are located in two separate sections.

a) fiction
b) non-fiction

A romantic novel about the Civil War would be found in the____________ section.

a) fiction

2

A history of the Civil War would be located in the (select "a" or "b") section.

a) fiction
b) non-fiction

b) non-fiction

3

In libraries, fiction books and non-fiction are located on (the same/different) shelves.

Would a detective story and a geography text-book be on the same shelf?

different

no

---

*M. Robb, S. Margulies, and I. A. Goldberg

4

In some libraries, fiction books are placed on the left side of the room and non-fiction books are placed on the right side.

Which of the following types of books would be on the left side:

a) a detective story
b) a how-to-do-to book on stamp collecting
c) an arithmetic text-book
d) a book of poems

a) a detective story

5

Books in the library are separated into two sections,______________and____________.

fiction

non-fiction

6

There is an alphabetical list of all the books in the library.

Would both fiction and non-fiction books be in this list?

yes

7

The alphabetical list of library books is printed on file cards.

This list is called a c___d catalog.

card

8

Sears and Roebuck prints a book which lists seeds. This list is called a seed catalog.

The alphabetical list of library books is called a ________________________.

card catalog

9

The card catalog lists (some/all) of the books in the library.

The easiest way to find out if your library has a copy of "The Three Musketeers" is to look in the ________ ________.

all

card catalog

10

Books in a library are separated into _________ and ________.

Every book in the library is listed in the __________ __________.

fiction

non-fiction

card catalog

11

People's names in the telephone book are listed in alphabetical order of last names.

Which of the following names is listed first:

a) Ben Jones
b) Sam Davis

b) Sam Davis

12

As in the telephone book, author's names in the card catalog are listed in alphabetical order of last names.

If you wanted to find the name of Mark Twain, would you look under Mark or Twain?

Twain

13

Which of the following names would be listed first?

a) William Shakespeare
b) Samuel Clemens
c) Nathaniel Hawthorne

b) Samuel Clemens

14

The cards in the card catalog are like the names in the telephone book because they are both arranged in _____ order.

alphabetical

15

If you wanted to know whether your library has a book by Abraham Lincoln, you would look it up under his (first/last) name in the card catalog.

last

16

799.2 Boyle, John
B46 Shooting for Deer in
Northern Michigan

This is a reduced copy of a card from the card catalog. (The actual card is approximately 3 inches by 5 inches in size.)

The author's name appears on the (top/bottom) of the card.

top

17

Which of the following authors would be listed after the other two in the card catalog:

a) Booth Tarkington
b) Bret Harte
c) Jack London

a) Booth Tarkington

18

429.13 Haskins, Charles
H14 How to Identify
Airplanes

This card comes from the card catalog.

The author's name appears on the (top/bottom) of the card.

Is the title of the book also on the card?

top

yes

19

F Treasure Island
Robert Louis Stevenson

This card also comes from the catalog.

The author's name is on (top/bottom).

The book title is on (top/bottom).

bottom

top

20

Some catalog cards have the author's name on top. Some have the book-title on top.

All catalog cards have the __________ name and the book __________.

author's

title

21

If you look at a card with the author's name on top, will it always have a title of the book underneath?

yes

22

Cards with the author's name on top are called author cards. Cards with the book title on top are called title cards.

F Tom Sawyer
Clemens, Samuel

Is this an author card or a title card?

title card

23

F Steinbeck, John
The Grapes of Wrath

This card is an ____________________.

author card

24

A catalog card has "Huckleberry Finn" printed at the top.

This card is a _________ card.

Is the author's name also printed on the card?

title

yes

25

As with author's names, book titles are also listed in alphabetical order in the card catalogs. Titles are listed in order of the first word.

Which of the following book titles would be listed first:

a) Huckleberry Finn
b) Captain Blood
c) Two Years Before The Mast

b) Captain Blood

26

"Black Beauty" would be placed (before/after) "Two Years Before The Mast" in the card catalog.

before

27

All the cards in the card catalog are arranged in a single alphabetical order. The title cards are not located separately from the author cards.

What would be the order of the following cards:

a) ____ 629.13 How to Identify Airplanes
414 Haskins, Charles

b) ____ F Call of the Wild
London, Jack

c) ____ F Sabatini, Rafael
Captain Blood

b)
a)
c)

28

If the first word of the title of a book is The or A or An, the title card is listed in alphabetical order of the second word.

The card for "The Swiss Family Robinson" would be filed under (select "a" or "b").

a) The
b) Swiss

b) Swiss

29

The card for "The Swiss Family Robinson" would come (before/after) the card for "Tom Sawyer".

before

30

Which of the following author's names or book titles would appear first in the card catalog:

a) The Iliad
b) Jack London
c) National Velvet

a) The Iliad

31

The library contains both fiction and non-fiction books. Fiction books have the letter F at the left of the catalog card. Non-fiction books have a number at the left of the catalog card.

F Steinbeck, John
The Grapes of Wrath

"The Grapes of Wrath" is a_________book.

fiction

32

629.13 Haskins, Charles
H. 14 How to Identify Airplanes

"How to Identify Airplanes" is a _________book.

non-fiction

33

To find out whether a book is fiction or non-fiction, you would look in the__________ __________.

card catalog

34

F Shakespeare, William
A Midsummer Night's Dream

What is the title of this book?

What is the author's name?

Is it fiction or non-fiction?

A Midsummer Night's Dream

William Shakespeare

fiction

35

A list of all the books in the library is called the ________________.

Each card gives both the ___________ and the _________ of the book.

The card also tells whether the book is fiction or ________.

card catalogue

author's name

title

non-fiction

36

If the first word of the title of a book is an article such as A, An or The, it is omitted from the title on top of the catalog card.

This is done because (use your own words).

these words are not important to the titles, or there are so many titles starting with these words.

37

The books on the fiction shelves of the library are arranged in the alphabetical order of author's last names.

Would "Oliver Twist" by Charles Dickens and "The Three Musketeers" by Alexander Dumas be near each other?

yes

38

"Oliver Twist" would be placed on the fiction shelf (before/after) a book by Thomas Abbott.

It would be (before/after) a book by George Stine.

after

before

39

Could you easily find a book on the fiction shelves of the library if you only knew the title and did not look up the author's name in the card catalog?

no

40

If you wanted to find a book on the fiction shelves and you only knew the title, you would look up the book title in the card catalog.

This card would tell you the_______________.

author's name

41

If you wanted to find a fiction book called "The Prince and The Pauper" and did not know the author, what word would you look for in the card catalog?

Prince

42

In most libraries special types of fiction books such as Mysteries and Westerns are kept on separate shelves from the rest of the novels.

Are these books listed in the card catalog?

yes

43

The shelves for special types of fiction are identified by signs which show the type of book.

If you wanted to read a Mystery, but did not have any particular one in mind, you would go to the special shelf marked________________.

MYSTERY

44

The cards in the card catalog have a special symbol for books on special shelves. For example SS on a card means that the book is on the Short Story shelf.

If the catalog card had the symbol DR on it, which of the following shelves would include the book:

a) MYSTERY
b) DRAMA
c) WESTERN

b) DRAMA

45

If a catalog card had the symbol for Mystery on it, would the book be in the non-fiction section of the library?

Where would it be?

no

on the special fiction shelf for Mysteries

46

F Murder in the Garden
Sayers, Dorothy

Would this book be on the special shelf for Mysteries?

In which part of the library would you look for it?

no (if you were wrong, please go back to step 42 and review)

On the fiction shelves, among the S authors

47

If you looked for a book in the card catalog and the card had $\begin{matrix}530\\G51\end{matrix}$ on it, the book would be in the________section of the library.

non-fiction

48

All books in the non-fiction section of the library have two numbers printed on the back of the book cover. These numbers are arranged one over the other.

$\begin{matrix}360\\G51;\end{matrix}$ $\begin{matrix}251\\A18;\end{matrix}$ or $\begin{matrix}470\\L12\end{matrix}$ are all examples of these numbers.

The numbers for each book are also printed on the __________ _________of that book.

catalog cards

49

All the non-fiction books are arranged in numerical order of the top numbers which are printed on the book covers. All fiction books are arranged in __________ order of the author's __________ name.

alphabetical

last

50

The books in the non-fiction section of the library are arranged in order of the ____________________ printed on the book covers.

top numbers

APPENDIX F: THE FIRST 46 FRAMES OF A PROGRAM IN STOCKS, BONDS, AND THE OPERATION OF THE STOCK EXCHANGE

Prepared by Automated Teaching Systems, Inc. *

1

A railroad needs $950,000 to buy tank cars. It issues 1,000 bonds which are offered for sale to the public at $950 each.

If all the bonds are sold, the railroad will realize $__________.

$950,000

2

At the end of a ten year period, each railroad bond which was sold will be redeemed by the railroad at its face value of $1,000.

Each bond costs $950 at purchase. At the end of ten years, each bond will make a profit of $__________ for the bondholder.

$50

3

The day on which the face value of a bond is redeemed is called the date of maturity.

If 1,000 bonds are sold, each having a face value of $1,000, the total amount which must be returned to the bondholders on the date of maturity is $__________.

$1,000,000

---

*J. Reid (edited by S. Margulies and I. A. Goldberg).

4

The total profit to an investor who purchases a utilities-bond for $1,200 with a 20-year maturity value of $1,500 is $________.

The profit per year is $________.

The total profit per year from two such bonds would be $________.

$300

$15

$30

5

The day on which a bond is redeemed at face value is called the__________.

date of maturity.

6

In addition to its growth from purchase price to face value at maturity, a bond also pays annual interest on its face value.

If you purchase a $1,000 (face value) railroad-bond having an annual interest rate of 3 1/2%, the bond would earn $_________ per year.

$35

7

A utilities-bond has a face value of $10,000 at maturity after 25 years. It sells for $9,200 and pays an annual interest of 3%.

The annual interest earned is $________.

The profit from the growth of the bond to its maturity value is $________when it is redeemed.

The accumulated total return to the investor from all sources over and above the purchase price is $_______ when the bond is redeemed.

$300

$800

$8,300 (this appears to be a large return, but remember that it takes 25 years to accumulate)

8

Which of the following does not represent a source of return on a bond investment?

a) Interest
b) Dividend
c) Growth to maturity

b) Dividend

9

By issuing bonds, a company has a means of borrowing money.

To a bondholder, each bond represents (select "a" or "b")

a) part ownership of the company.
b) a debt of the company to him.

b) a debt of the company to him.

10

A security is a certificate which may represent either ownership or debt.

One type of security representing debt is called a________.

bond

11

The obligation to pay the interest and the maturity value of a railroad-bond must be met by the (select "a", "b" or "c")

a) New York Stock Exchange.
b) issuing company.
c) U. S. Government.

b) issuing company.

12

The two obligations of a bond issuing company to its bondholders are____________and__________.

payment of interest on face value (any equivalent statement is correct)

redemption at maturity of face value (any equivalent statement is correct)

13

The money that Firestone makes from selling tires is called earnings. Firestone assigns part of its earnings to pay obligations on bonds.

If 1961 earnings are not sufficient to meet its bond obligations, Firestone (can/cannot) legally skip its bond-interest payment?

can (the payment must be made up in a future year)

14

The money that Ford makes from selling cars is called __________.

earnings

15

In addition to bonds, a company may sell a type of security called common stock to raise funds.

If a railroad issues 500,000 shares of common stock which are brought by the public at a price of $25 per share, the railroad will realize $__________ . (Ignore selling fees)

100 shares will cost $__________. (Ignore purchase fees)

$12,500,000

$2,500

16

The price of common stock may fluctuate with public demand.

XYZ Corp. has very good prospects and many people want to buy its common stock. The per-share selling price goes up from $15 to $17.

If you had purchased 100 shares at the lower price, and sold them at the higher price, your profit would be $________ . (Ignore brokerage fees)

$200

17

The XYZ Corp. manufactures railroad cars, but more people are traveling by plane and the future growth of railroads does not look favorable.

In this case, what may happen to the per-share price of XYZ Corp. common stock?

It will probably go down (any equivalent statement is correct)

18

Money made from the sale of stock at a profit is called capital gain.

What is capital loss?

Money lost from the sale of stock at a lower price than originally purchased. (Any equivalent statement is correct)

19

In addition to potential capital gains, a stockholder may also get a return on his investment by means of a common stock dividend.

If a dividend of $1 per share is declared, the total return on 300 shares is $______.

$300

20

A common stockholder may get a return on his investment by________gain and__________payments.

capital

dividend

21

Like bond interest payments, common stock dividends are paid out of company________.

earnings.

22

Stock dividends usually reflect earnings.

When earnings are high, dividends are increased to give the stockholder a higher return on his investment.

Bond interest payments (also vary/do not vary) as company earnings go up or down?

do not vary

23

Bond obligations are considered as fixed charges to be paid by the issuing company.

Stock dividend payments (are also/are not) considered as fixed charges.

are not

24

When company earnings are distributed, fixed bond obligations are paid off first.

Remaining earnings may be paid as dividends to the shareholders of_______.

common stocks (or stocks)

25

If annual earnings are low and there is only sufficient money to pay fixed bond obligations, a dividend (will/will probably not) be paid to common stock shareholders.

will probably not

26

When company earnings are high, return on investment is greater for holders of ________ than for ________.

common stocks

bonds

27

Some companies have managed to pay a regular dividend for the past 20 years.

The market price of the common stock of these companies should be relatively (select "a" or "b")

a) high
b) low

a) high

28

Which of the following is more likely to be skipped when earnings are low?

a) Dividends
b) Bond interest payments

a) Dividends

29

Match the security with its basic advantage to the holder.

a) Common stock	A) Offers smallest risk of losing money
b) Bond	B) Offers opportunity for higher return

a) Common stock--B) Offers opportunity for higher return

b) Bond --A) Offers smallest risk of losing money

30

Company A, a toy company with few physical facilities, has high earnings due to a recent success of one of its products.

Company B, a steel company with vast physical holdings, is presently operating at a loss.

Company_______offers the better common stock investment.

Company_______is the better bond investment.

A

B

31

Is it possible for a bond investment in one company to be more risky than a common stock investment in another company?

Yes (a bond held with a company which may go bankrupt and not have sufficient assets to cover its bond obligations is clearly a more risky investment than common shares in a powerful, deeply rooted company)

32

Ultimately, the soundness of any security depends on the soundness of the___________.

company

33

A share of stock represents part ownership in a company.

Ownership (is also/is not) represented by a bond.

is not

34

A bond represents a________of the issuing company.

Both stock and bond certificates are called_______ .

debt

securities

35

A common stock shareholder has a voice in the policies of a company because stock represents_________.

ownership

36

One share of common stock carries the right of one vote at stockholders meetings where company policy is decided.

Which of the following is sufficient for control of company policy?

a) Ownership of 50% of common shares
b) Ownership of at least 51% of common shares
c) Ownership of 95% of company bonds
d) Ownership of 35% of company shares

b) Ownership of at least 51% of common shares

37

The two types of securities which have been discussed so far are__________and__________________.

bonds

common stocks

38

A third type of security is called preferred stock.

Like the owner of common stock, the investor in preferred stock can get a return from______________and __________.

capital gain

dividends

39

Preferred stock has a claim on earnings which is prior to that of common stock but after that of bonds.

List the order in which the securities have claim to earnings:

1st priority -- ________________
2nd priority -- ________________
3rd priority -- ________________

1st priority -- Bonds

2nd priority -- Preferred stocks

3rd priority -- Common stocks

40

Many preferred stocks pay a fixed dividend in regular quarterly, semi-annual or annual payments.

This type of preferred stock dividend payment is similar to payment of (select "a" or "b").

a) bond interest
b) common stock dividend

a) bond interest

41

Some preferred stocks have a cumulative dividend feature.

With these stocks, if the issuing company skips one or more fixed dividend payments, it must pay off all dividend arrears before a common stock dividend can be declared.

Does the cumulative dividend feature guarantee the preferred stockholder of getting his fixed dividend?

No (the company may never have sufficient earnings to pay fixed dividends)

42

A man owns 400 shares of preferred stock paying a fixed annual cumulative dividend of $3. The company misses 5 dividend payments. At the end of the sixth year, it declares a common stock dividend

The total dividend which must first be paid to the holder of the 400 preferred shares is $_______________.

$7,200 (6 x $1,200)

43

Under some conditions, it is possible for a company to pay a higher dividend on common shares than the fixed dividend paid on preferred shares.

This is most likely to occur when earnings are (high/low).

In this case, it would be more profitable to hold __________ shares than __________ shares.

high

common

preferred

44

There are many features which are designed to make preferred stocks more attractive than common stocks.

One such feature is the payment of____________.

cumulative dividends (or fixed dividends)

45

Preferred stocks are an attempt to combine the best features of bonds and common stocks.

They provide a higher return than bonds and are considered to be a ______________________________ investment than _______________.

safer (any equivalent statement is correct)

common stock

46

A Stock Exchange provides a place where securities may be traded between buyers and sellers. The Exchange itself does not issue securities, nor does it buy or sell them.

Is it possible to buy 10 shares of IBM common stock from the New York Stock Exchange?

No

APPENDIX G: A FOUR-PAGE SAMPLE SEQUENCE IN ARITHMETIC

Prepared by Norman A. Crowder

page 1

We have learned that the numbers multiplied together to form a product are called the factors of that product.

There are some interesting and important results when the same number is used as a factor several times. A knowledge of this process is essential to an understanding of exponents, logarithms, the slide rule, the operation of certain computers, and of many other powerful mathematical tools.

Here's an example of the same number used as a factor more than once:

In the multiplication

$$3 \times 3 = 9$$

the number 3 appears as a factor twice. Of course we can use the same factor more than twice.

What is the product when 2 is used as a factor 3 times? Turn to the page which corresponds to the right answer.

6	page 3
8	page 6
9	page 7

page 3
(from page 1)

YOUR ANSWER: When 2 is used as a factor three times, the product is 6.

You merely used 2 and 3 as factors. $2 \times 3 = 6$. This is incorrect.

We want the product you would get if you used the number 2 as a factor three times. In other words, we want the result of the multiplication

$$2 \times 2 \times 2 = ?$$

Now return to page 1 and choose another answer.

page 6
(from page 1)

YOUR ANSWER WAS "8".

You are correct.

$$2 \times 2 \times 2 = 8$$

The mathematical symbol meaning "form the product reached by using 2 as a factor three times" is

$$2^3$$

It means

use the number 2^{3}—this many times

as a factor.

Similarly, $2 \times 2 \times 2 \times 2$ could be written as 2^4, 3×3 as 3^2, etc.

What would 3^4 be?

$3^4 = 3 \times 4 = 12$	page 2
$3^4 = 4 \times 4 \times 4 = 64$	page 5
$3^4 = 3 \times 3 \times 3 \times 3 = 81$	page 8

page 7
(from page 1)

YOUR ANSWER: When 2 is used as a factor three times, the product is 9.

Your answer is incorrect. You have used the number 3 as a factor twice.

$$3 \times 3 = 9.$$

However, you were asked to use the number 2 as a factor three times.

$$2 \times 2 \times 2 = ?$$

Now return to page 1 and choose another answer.

APPENDIX H: FIFTY FRAMES OF A

Prepared for Science Research Associates, Inc.[*]

0 8	48.	Expression	Replacements	Value
		$6xt$	'x' with '0' 't' with '8'	☐
		$6(x+t)$	'x' with '0' 't' with '☐'	48

32 1	49.	Expression	Replacements	Value
		$16\Delta s$	'Δ' with '-1' 's' with '-2'	☐
		$\frac{1}{6}\,\alpha\, z$	'α' with '$-\frac{1}{2}$' 'z' with '-12'	☐

72 -1	50.	Expression	Replacement	Value
		$15(5+\Delta)$	'Δ' with '$-\frac{1}{5}$'	☐
		$(4+2)y$	'y' with '$-\frac{1}{6}$'	☐

3 -4	51.	Expression	Replacements	Value
		$(a+b)8$	'a' with '$\frac{1}{4}$' 'b' with '$\frac{1}{8}$'	☐
		$(k+m)9$	'k' with '$-\frac{1}{3}$' 'm' with '$-\frac{1}{9}$'	☐

---

[*] Lewis D. Eigen, Jerome D. Kaplan, and Ruth Emerson

<table>
<tr><td>$\frac{1}{4}$
$-\frac{1}{5}$</td><td>52.</td><td>
<table>
<tr><th>Expression</th><th>Replacements</th><th>Value</th></tr>
<tr><td>$4(a+k)$</td><td>'a' with '$\frac{1}{2}$'<br>'k' with '$\boxed{\quad}$'</td><td>3</td></tr>
<tr><td>$(\beta+\gamma)5$</td><td>'β' with '$-\frac{1}{5}$'<br>'γ' with '$\boxed{\quad}$'</td><td>-2</td></tr>
</table>
</td></tr>
<tr><td>$a+2$
distributive</td><td>53.</td><td>$6a+6(2) = 6(\boxed{\quad})$ by the $\boxed{\qquad\qquad}$ property.</td></tr>
<tr><td>False.
[$m(r+s) = mr+ms$.]</td><td>54.</td><td>By the distributive property, $m(r+s) = mr+s$ for all real numbers m, r, and s. $\boxed{\quad}$ (True or false?)</td></tr>
<tr><td>6(7)
or
42</td><td>55.</td><td>$6(1+2+7) = 6(1)+6(2)+\boxed{\quad}$.</td></tr>
<tr><td>7</td><td>56.</td><td>If 'x' is replaced with '$\frac{1}{2}$', 'y' with '$\frac{1}{4}$', and 'z' with '$\frac{1}{8}$', then
$8(x+y+z) = 8(\frac{1}{2})+8(\frac{1}{4})+8(\frac{1}{8})$.
Multiply out and write your answer:
$8(\frac{1}{2})+8(\frac{1}{4})+8(\frac{1}{8}) = \boxed{\quad}$.</td></tr>
<tr><td>-4</td><td>57.</td><td>If 'x' is replaced with '-1', 'y' with '-2', and 'z' with '1', then the value of the expression '$2(x+y+z)$' is $\boxed{\quad}$.</td></tr>
<tr><td>18</td><td>58.</td><td>
<table>
<tr><th>Expression</th><th>Replacements</th><th>Value</th></tr>
<tr><td>$6(x+y+z)$</td><td>'x' with '2'<br>'y' with '1'<br>'z' with '0'</td><td>$\boxed{\quad}$</td></tr>
</table>
</td></tr>
</table>

18
5

59.

Expression	Replacements	Value
$(3+1+\frac{1}{2})\Delta$	'Δ' with '4'	☐
$(\alpha+\beta+\gamma)9$	'α' with '$-\frac{1}{3}$' 'β' with '$-\frac{1}{9}$' 'γ' with '1'	☐

Two.

60. We can have equations with more than one pronumeral. '$x+y=5$' is an equation. How many pronumerals are there in this equation? ☐

Yes.

61.

$$x+y=5.$$

This equation has two pronumerals.
If we replace 'x' with '2' and 'y' with '3', we get a true equation.
If we replace 'x' with '1' and 'y' with '4', do we get a true equation? ☐ *(Yes or no?)*

Yes.

62.

$$x+y=5.$$

If we replace 'x' with '6' and 'y' with '-1', do we get a true equation? ☐ *(Yes or no?)*

No.

63.

$$x+y=5.$$

If we replace 'x' with '3' and 'y' with '5', do we get a true equation? ☐ *(Yes or no?)*

Yes.

64.

$$x+y=5.$$

If we replace 'x' with '5' and 'y' with '0', do we get a true equation? ☐ *(Yes or no?)*

5	65.	After the pronumerals of an equation are replaced with numerals, the equation is either true or false. In the equation '$2x+y=5$' we replace pairs of pronumerals, 'x' and 'y'. Let us agree that a numeral replacing 'x' will name the first element of an ordered pair and a numeral replacing 'y' will name the second element of the ordered pair. Then the ordered pairs (2, 1) and (0, $\boxed{}$) are members of the solution set of the equation '$2x+y=5$'.
Yes.	66.	$x+y=5.$ Let a replacement for 'x' denote the first element of an ordered pair. Let a replacement for 'y' denote the second element of the ordered pair. Is (8, −3) an element of the solution set of '$x+y=5$'? $\boxed{}$ *(Yes or no?)*
(0, 6) and (−2, −3)	67.	$x+y=5.$ Which of the following ordered pairs are **not** elements of the solution set: (3, 2), (99, −94), (0, 6), (−3, 8), (−2, −3), (−13, 18)? $\boxed{}$
$\neq$ *or* $<$ *or* $\leq$	68.	$x-t=4.$ Let a replacement for 'x' denote the first element of an ordered pair. Let a replacement for 't' denote the second element of the ordered pair. (6, 2) is an element of the solution set of '$x-t=4$' since $6-2=4$. (2, 6) is **not** an element of the solution set since $2-6 \boxed{} 4$.
(2, 6) and (−5, −1)	69.	$x-t=4.$ Which of the following ordered pairs are **not** elements of the solution set: (6, 2), (2, 6), (−1, −5), (−5, −1)? $\boxed{}$

13	70.	$\psi - m = 12.$ Let a replacement for 'ψ' denote the first element of an ordered pair. Let a replacement for 'm' denote the second element of the ordered pair. Let **U** = {(18, 3), (24, 12), (25, 13)}. The solution set of '$\psi - m = 12$' is {(24, 12), (25, $\boxed{}$)}.
relation	71.	The solution set of an equation or inequation with two pronumerals is made up of ordered pairs. In other words, it is a $\boxed{\text{r}}$.
ordered pairs	72.	A relation is a set of $\boxed{}\boxed{}$.
(−3, −3)	73.	$x = b.$ Let a replacement for 'x' denote the first element of an ordered pair. Let a replacement for 'b' denote the second element of the ordered pair. 'Solve' is a short way to say 'find the solution set of'. Solve '$x = b$' when **U** = {(4, 4), (2, 4), (−3, −3), (8, 11)}. Answer: {(4, 4), $\boxed{}$}.
{(0, 0), (6, 2), (9, 3)}	74.	$\frac{d}{3} = k.$ Let a replacement for 'd' denote the first element of an ordered pair. Let a replacement for 'k' denote the second element of the ordered pair. Solve '$\frac{d}{3} = k$' when **U** = {(0, 0), (1, 0), (6, 2), (9, 3), (10, 4)}. $\boxed{}$
No.	75.	Does (2, 2) belong to the solution set of '$\frac{a+r}{4} = r$'? $\boxed{}$ *(Yes or no?)*

{(3, 1), (9, 3)}	76.	$\frac{y}{r} = 3$. Let a replacement for 'y' denote the first element of an ordered pair. Let a replacement for 'r' denote the second element of the ordered pair. Solve '$\frac{y}{r} = 3$' when **U** = {(0, −1), (0, 1), (2, 2), (3, 1), (9, 3)}. $\boxed{\qquad\qquad}$
{(1, 1), (5, 3)}	77.	Let replacements for 'n' and 'h' denote respectively first and second elements of an ordered pair. Solve '$\frac{n+1}{2} = h$' when **U** = {(0, 0), (1, 1), (2, 3), (4, 2), (5, 3)}. $\boxed{\qquad\qquad}$
solution set	78.	We can have inequations with more than one pronumeral. $x > y$. Let replacements for 'x' and 'y' denote respectively first and second elements of an ordered pair. (5, 4) is an element of the solution set of '$x>y$' since 5>4. (2, 3) is not an element of the $\boxed{\qquad\quad}$ $\boxed{\qquad}$ since 2 is not greater than 3.
(3, 1)	79.	Let replacements for 'z' and 'f' denote respectively first and second elements of an ordered pair. Solve '$z > f$' when **U** = {(5, 2), (3, 1), (2, 5), (−3, 2)}. Answer: {(5, 2), $\boxed{\qquad}$}.
{(4, 2), (2, 1)}	80.	Let replacements for 'ψ' and 'δ' denote respectively first and second elements of an ordered pair. Solve '$\psi > \delta$' when **U** = {(4, 2), (5, 9), (2, 1), (1, 2)}. $\boxed{\qquad\qquad}$
2	81.	Let replacements for 'x' and 'y' denote respectively first and second elements of an ordered pair. Solve '$y > x$' when **U** = {(1, 2), (2, 1)}. Answer: {(1, $\boxed{\quad}$)}.

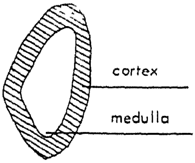
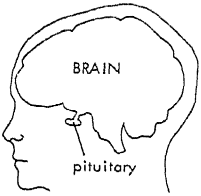
(0, 2) [*(2, 0) is incorrect. The replacement of 'Δ' denotes the second element, and Δ must be larger than θ.*]	82.	Let replacements for 'θ' and 'Δ' denote respectively first and second elements of an ordered pair. Solve '$\Delta > \theta$' when **U** = {(2, 0), (0, 2)}. Answer: {☐}.
{(8, 11)} *(Don't forget the set braces.)*	83.	Let replacements for 'b' and 'a' denote respectively first and second elements of an ordered pair. Solve '$a > b$' when **U** = {(8, 11), (11, 8)}. ☐
{(2, 2)}	84.	Let replacements for 't' and 'y' denote respectively first and second elements of an ordered pair. Solve '$y \geq t$' when **U** = {(2, 2), (3, −1)}. ☐
{(0, 1)}	85.	Let replacements for 'g' and 'r' denote respectively first and second elements of an ordered pair. Solve '$\frac{g}{2} < r$' when **U** = {(1, 0), (0, 1), (2, 1)}. ☐
Yes.	86.	Let replacements for 'y' and 'q' denote respectively first and second elements of an ordered pair. Does (10, 3) belong to the solution set of '$\frac{y}{q} > 3$'? ☐ *(Yes or no?)*
{(0, 1), (1, 1)}	87.	Let replacements for 's' and 'x' denote respectively first and second elements of an ordered pair. Solve '$\frac{s+4}{5} \leq x$' when **U** = {(0, 0), (0, 1), (1, 1), (1, 0)}. ☐
No.	88.	Let replacements for 'n' and 'z' denote respectively first and second elements of an ordered pair. Does (−1, 1) belong to the solution set of '$\frac{n+3}{3z} \geq 1$'? ☐ *(Yes or no?)*

{(1,1), (1,2)}	89.	Let replacements for 'e' and 'c' denote respectively first and second elements of an ordered pair. Solve '$\frac{4e+2}{c-3} < 0$' when **U** = {(1,1), (1,2), (4,4), (2,5)}. $\boxed{}$
(8,7)	90.	Let replacements for 'x' and 'm' denote respectively first and second elements of an ordered pair. Solve '$x = m+1$' when **U** = {(5,4), (9,11), (8,7)}. Answer: {(5,4), $\boxed{}$}.
{(4,6), (0,2)}	91.	Let replacements for 'g' and 'd' denote respectively first and second elements of an ordered pair. Solve '$d = g+2$' when **U** = {(4,6), (6,5), (0,2)}. $\boxed{}$
{(0,3), (0,8)}	92.	Let replacements for 'a' and 'b' denote respectively first and second elements of an ordered pair. Solve '$a+b = b$' when **U** = {(0,3), (2,0), (3,0), (0,8)}. $\boxed{}$
Yes.	93.	$a+b = b+a.$ Let replacements for 'a' and 'b' denote respectively first and second elements of an ordered pair. Is (8,11) an element of the solution set of '$a+b = b+a$'? $\boxed{}$ *(Yes or no?)*
No.	94.	$a+b = b+a.$ Try some more ordered pairs, such as (5,3), (½,1), (−2,0). Can you find any ordered pair of replacement values that will not yield a true equation? $\boxed{}$ *(Yes or no?)*
identity	95.	Since any pair of replacement values will yield a true equation, the solution set of '$a+b = b+a$' is **U**. We say that this equation is an $\boxed{\text{id}}$.

b	96.	Another way to say that '$a+b = b+a$' is an identity is to say that for any real numbers a and b, $a+b = \square + a$.
Δ	97.	'$s + \Delta = \Delta + s$' is an identity because it is a true equation for all possible pairs of replacement values for 's' and '$\square$'.
Because the solution set is the universe of discourse. *or* Because '$m+t = t+m$' is a true equation for all possible pairs of replacement values for 'm' and 't'. *or* *an equivalent answer*	98.	Why is '$m+t = t+m$' an identity? $\square$

APPENDIX I: A PROGRAM IN THE ELEMENTS OF CORTICOSTEROID

Prepared by Basic Systems, Inc.

20.  	
40.  	
60. pituitary; ACTH	

1.

Adrenal glands
Pituitary gland
Thyroid gland
Parathyroid gland

All of the above organs secrete substances which affect processes in various parts of the body. What word do the names of these organs have in common?

(TURN PAGE FOR ANSWER AND QUESTION 2.)

21.

(THIS IS NOT QUESTION 2. QUESTION 2 IS ON THE NEXT PAGE.)

An important class of hormones known as the steroids is produced only by the testes, the ovaries, the placenta and the adrenal cortices (plural of cortex). The steroids produced by the adrenal ____________ (plural) are called corticosteroids.

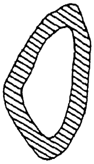
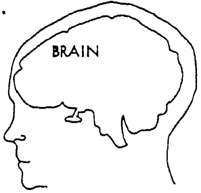
41.

A stalk joins the pituitary gland to the underside of the ____________.

61.

When the human body is subjected to certain environmental conditions such as extreme cold, the pituitary responds by secreting ACTH.

As a result the quantity of ____________ secreted by the adrenal cortex (increases/decreases) ____________.

19. medulla or adrenal medulla; cortex or adrenal cortex	20. Label the diagram of the adrenal gland shown below. 
39. pituitary; endocrine	40. The pituitary gland is about the size of a pea. It is joined to the underside of the brain by a stalk. Label the pituitary gland in the diagram below. 
59. pituitary; cortex; corticosteroids	60. The adrenal cortex responds by increasing its secretion of corticosteroids when the ____________ gland secretes the hormone ______________.

Answer to Question 1:

1. gland

2.

Organs that secrete substances affecting processes in various parts of the body are called ______________.

(TURN PAGE FOR ANSWER AND QUESTION 3.)

---

21. cortices

22.

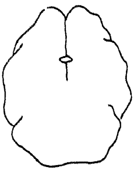
The steroids are a class of ______________ secreted only by the testes, ovaries, placenta and adrenal cortices.

---

41. brain

42.

Below is a diagram of the underside of the brain. Shade in the pituitary.



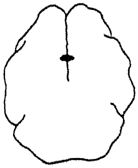
---

61. corticosteroids; increases

62.

An increase in the secretion of ACTH by the ______________ gland results in a(n) (increase/decrease) __________________ in corticosteroid secretion by the adrenal ______________ (which part?).

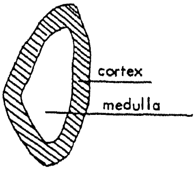
18. cortex; outer	19. The inner part of the adrenal gland is the ________ and the outer part is the ______________.
38. pituitary	39. The ____________ gland secretes many hormones, some of which stimulate other ____________ glands to secrete their own hormones.
58. bloodstream; corticosteroids	59. ACTH is the __________(from where) hormone that stimulates the adrenal __________(which part) to secrete ______________
78. The adrenal cortices produce smaller amounts of corticosteroids and become atrophic. (The adrenal medulla is not affected.)	GO ON TO CHAPTER 2, PAGE 22

2. glands	3. Glands that secrete substances directly into the bloodstream are endocrine (ên′ dō crîne) glands. The secretions of ________ glands travel in the bloodstream to various parts of the body.
22. hormones	23. The adrenal cortices, testes, ovaries and placenta secrete the class of hormones known as the ________.
42. 	43. The pituitary produces a hormone which controls the secretion of most of the hormones from the adrenal cortex. In other words, the amount of ________ (type of hormones) found in the bloodstream is largely dependent upon a hormone from the pituitary gland.
62. pituitary; increase; cortex or cortices	63. A large amount of corticosteroids in the bloodstream inhibits the secretion of ACTH. After the hormone ________ has stimulated the secretion of corticosteroids, the corticosteroids travel in the bloodstream to the pituitary where they (increase/decrease) ________ the rate of ACTH secretion.

17. medulla; inside or inner	18. The word "cortex" comes from the Latin expression for "bark of a tree". Just as the bark is the outer part of a tree, the adrenal __________ is the __________ part of the adrenal gland.
37. ovary, testes, thyroid, adrenal cortex	38. The ovary, the testes, the thyroid and the cortex are under the control of the pit__________ gland.
57. adrenalin; noradrenalin; pituitary	58. The pituitary hormone ACTH travels in the.__________ to the adrenal cortex. Upon reaching the adrenal cortex, ACTH stimulates the cortex to secrete __________.
77. pituitary; corticosteroids	78. Describe briefly what happens in the adrenal glands if the pituitary is destroyed by disease or removed by surgery.

3. endocrine	4. The thyroid gland secretes a hormone called thyroxin into the bloodstream. The ovary secretes a hormone called estrogen into the bloodstream. In general, the substances that are secreted into the ____________ by endocrine glands are called ____________.
23. steroids	24. How many different sets of steroid-producing glands are there in the body of the normal male?
43. corticosteroids	44. The ovaries, testes, thyroid and adrenal cortices are target organs of the pituitary gland. In general, we say that an organ is a ____________ ____________ of the pituitary if the pituitary stimulates that organ.
63. ACTH; decrease	64. ACTH (stimulates/inhibits) ____________ the secretion of corticosteroids, whereas corticosteroids (stimulate/inhibit) ____________ the secretion of ACTH.

16.



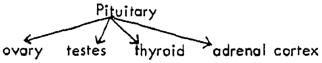
17.

The ____ulla composes the ________ part of the adrenals.

---

36. medulla: adrenalin and noradrenalin; cortex: corticosteroids

37.



The pituitary gland secretes a number of hormones, some of which stimulate other endocrines to release their own hormones. Write the names of the endocrine glands that are affected by hormones from the pituitary.

---

56. medulla or adrenal medulla

57.

The secretion of the hormones __________ and __________ from the adrenal medulla is not controlled by any of the hormones from the ________________ gland.

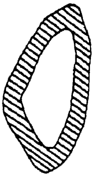
---

76. ACTH; inhibit

77.

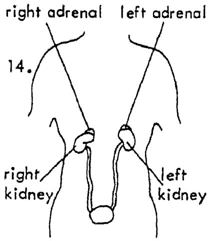
If the ________________ gland is destroyed, the adrenal cortices become atrophic and secrete smaller quantities of ____________________.

4. bloodstream; hormones	5. The pituitary gland secretes hormones into the bloodstream. Therefore, we call the pituitary an endocrine gland. The adrenal glands are also endocrine glands. Why?
24. two (2) (testes and adrenal cortices)	25. The ovaries produce primarily a certain kind of steroid called estrogen. The testes produce primarily a second kind of steroid called androgen. The placenta produces mainly the kind of steroid called progesterone. The adrenal cortices produce a fourth kind of steroids called corticosteroids. The steroid producing glands produce (the same/different) __________ steroids.
44. target organ	45. Only one part of the adrenals is affected by the pituitary. Name the part which is not affected by the pituitary.
64. stimulates; inhibit	65. The relationship between the pituitary and the adrenal cortices is a two way relationship. The hormone ______________ stimulates the secretion of corticosteroids and these in turn (inhibit/stimulate) __________________ the secretion of this pituitary hormone.

15. kidney; above the right kidney	16. Each adrenal gland consists of two parts. The inner part is the medulla and the outer part is the cortex. The diagram below shows an adrenal which has been sliced in half. Label this diagram. 
35. are not	36. Name the two parts of the adrenal gland and the hormones or class of hormones secreted by each part.
55. ACTH	56. Which part of the adrenal gland is not affected by ACTH?
75. medulla; atrophic	76. If a normal person is subjected to extreme heat, his pituitary secretes ____________. This hormone then stimulates the secretion of corticosteroids. The corticosteroids, in turn, travel in the bloodstream to the pituitary and ______________ the further secretion of ACTH.

5. because they secrete hormones into the bloodstream	6. Hormones are substances secreted into the ____________ by ______________ __________.
25. different	26. The steroids produced by the adrenal cortex are called cortico__________________.
45. medulla *or* adrenal medulla	46. The adrenal cortex is one of the ___________ organs of the pituitary.
65. ACTH; inhibit	66. If a doctor were to inject corticosteroids into the bloodstream, what effect would this have on the secretion of ACTH by the pituitary?

14.



15.

The left adrenal gland lies above the left _______________.
Where is the right adrenal located?

---

34. corticosteroids

35.

Only those hormones produced by the adrenal cortex are called corticosteroids. Adrenalin and noradrenalin (are/are not) ___________________ corticosteroids.

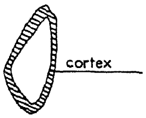
---

54. ACTH;
adrenal cortex

55.

In general, when referring to the pituitary hormone which stimulates the secretion of corticosteroids, you should use the abbreviation of this hormone rather than its lengthy name. Write the abbreviation of this pituitary hormone.

74.

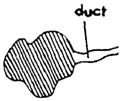


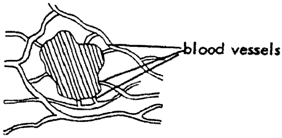
75.

ACTH does not affect the adrenal ____________(which part?). Therefore, this part of the adrenals does not become __________ when the pituitary is destroyed.

6. bloodstream; endocrine glands

7.





Certain glands, such as the salivary glands, secrete substances (not hormones) into ducts. Endocrine glands, on the other hand, are not connected to ducts; they secrete their hormones directly into the bloodstrea Endocrine glands are ____________less glands.

---

26. corticosteroids

27.

The ______________steroids are hormones secreted by the adrenal ______________ (which part?).

---

46. target

47.

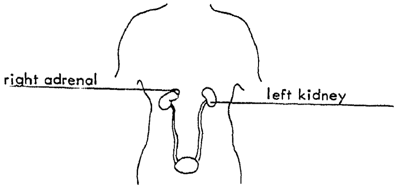
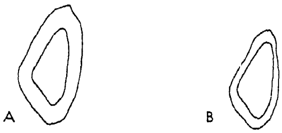
The ______________ gland secretes several hormones, one of which stimulates the adrenal __________ to secrete ____________________.

---

66. The secretion of ACTH would be inhibited.

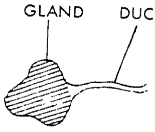
67.

ACTH (stimulates/inhibits) __________ the secretion of ______________, whereas corticosteroids (stimulate/inhibit) ______________ the secretion of ______________.

13. adrenals or adrenal glands; kidneys	14. The kidneys are shaped like lima beans and are located on the back wall of the body cavity, behind the intestines. Draw in the missing adrenal and fill in the missing labels. 
33. noradrenalin; hormones; medulla	34. The ______________ are the hormones produced and secreted by the adrenal cortex.
53. corticosteroids; adrenocorticotrophic hormone	54. _____dreno_____ortico_____rophic __ormone Write the missing letters in capitals below. This is the abbreviation of the pituitary hormone which affects the __________________________.
73. ACTH; atrophic; corticosteroids	74. Shade and label the part of the adrenal gland in diagram B that has become atrophic due to a lack of ACTH. 

7. ductless

8.



Why is the gland shown above probably not an endocrine gland?

---

27. corticosteroids;
cortex (cortices)

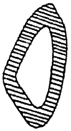
28.

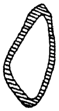
The adrenal cortex secretes several hormones into the bloodstream. Collectively these hormones are called ____________________

---

47. pituitary;
cortex;
corticosteroids

48.


A.


B.

The pituitary hormone which affects the adrenal cortex helps to maintain the size of the cortex by stimulating the production of corticosteroids. Which of the above adrenal glands was not affected by a sufficient amount of the pituitary hormone? (A or B)

---

67. stimulates;
corticosteroids
inhibit;
ACTH

68.

Explain the two-way relationship between ACTH and the corticosteroids.

12. endocrine; hormones	13. The human body contains two kidneys: one on the right side and one on the left. The human body also contains two adrenal glands. Since the prefix "ad" means "near" and the stem "renal" means "kidney", you might guess that each of the ____________ is near one of the _______________.
32. corticosteroids	33. Adrenalin and _______adrenalin are the ____________ produced by the adrenal ____________ (which part?)
52. adrenocorticotrophic; adrenal cortex or adrenal cortices	53. The hormone from the pituitary that stimulates the adrenal cortex and controls the secretion of ______________ from the adrenal cortex is ___dreno___ortico___rophic __ormone.
72. decrease	73. When the pituitary is removed, so that no more ________ is produced to stimulate the adrenal cortices, the cortices become ____________ and produce smaller amounts of _____________.

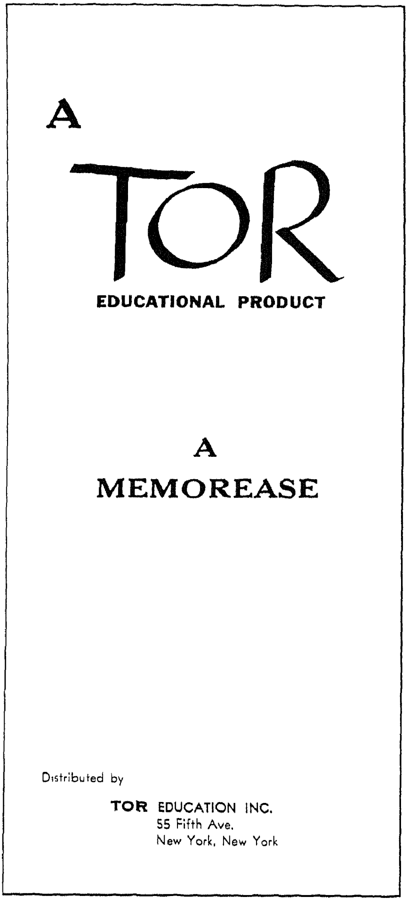
8. Endocrine glands are not connected to ducts. (or equivalent answer)	9. Substances secreted by duct glands are not called ______________, whereas substances secreted by endocrine glands are called ________________.
28. corticosteroids	29. The part of the adrenal gland that does not secrete corticosteroids secretes two important hormones called adrenalin (ă dre´na lĭn) and noradrenalin (nor´ă dre´na lĭn). The adrenal medulla secretes __________ and __________.
48. B	49. The suffix "trophic" means "nourishing". Thus, if a hormone is described as trophic, it ____________es or stimulates its target organ.
68. ACTH stimulates the secretion of corticosteroids while corticosteroids inhibit the secretion of ACTH. (or equivalent answer)	69. The word "atrophic" means almost the opposite of trophic. Whereas trophic means nourishing or stimulating, "atrophic" means a wasting away of an organ. Thus when an organ is described as atrophic, it is under____________________.

11. An endocrine gland is a ductless gland that secretes hormones directly into the bloodstream. (or equivalent answer)	12. The ovaries, testes, thyroid, pituitary, and adrenals are ____________ glands since they secrete __________ directly into the bloodstream.
31. bloodstream; adrenalin	32. *What is the name of the hormones produced only by the adrenal cortex?*
51. pituitary; adrenocorticotrophic; cortex	52. Adrenocortico __________ hormone stimulates the __________ ______________.
71. larger	72. If the pituitary were to stop secreting ACTH, the amount of corticosteroids would (increase/decrease) ______________.

9. hormones; hormones	10. Hormones are secreted by ____________________ glands. TURN BOOK OVER TO PAGE 11 FOR ANSWER TO QUESTION 10 AND PROCEED TO QUESTION 11.
29. adrenalin; noradrenalin	30. The name adrenalin is easy to remember because it consists of the two words "adrenal" and "in", and because adrenalin is one of the hormones secreted by the __________side part of the ____________ gland, which is the medulla. TURN BOOK OVER TO PAGE 11 FOR ANSWER TO QUESTION 30 AND PROCEED TO QUESTION 31.
49. nourishes	50. One of the hormones secreted by the pituitary is called adrenocorticotrophic hormone. adreno refers to the _______________ gland. cortico refers to the _______________ of the __________ gland. _________________ means nourishing or stimulating. TURN BOOK OVER TO PAGE 11 FOR ANSWER TO QUESTION 50 AND PROCEED TO QUESTION 51.
69. undernourished or understimulated	70. If the pituitary is destroyed or removed, the cortices of both adrenals are no longer stimulated by the hormone ___________. As a result the cortices become thin and undernourished. In other words, the adrenal cortices become _________ in the absence of the pituitary. TURN BOOK OVER TO PAGE 11 FOR ANSWER TO QUESTION 70 AND PROCEED TO QUESTION 71.

	11. Write one sentence using each of the following terms: endocrine gland — bloodstream hormones — secrete ductless
10. endocrine	
	31. The two hormones secreted into the __________ by the adrenal medulla are __________ and noradrenalin.
30. inside; adrenal	
	51. The __________ gland secretes adreno__________trophic hormone, which stimulates the adrenal __________ (which part).
50. adrenal; cortex; adrenal; trophic	
	71. The secretion of ACTH by the pituitary results in the secretion of (larger/smaller) __________ quantities of corticosteroids.
70. ACTH; atrophic	

APPENDIX J: A MEMOREASE



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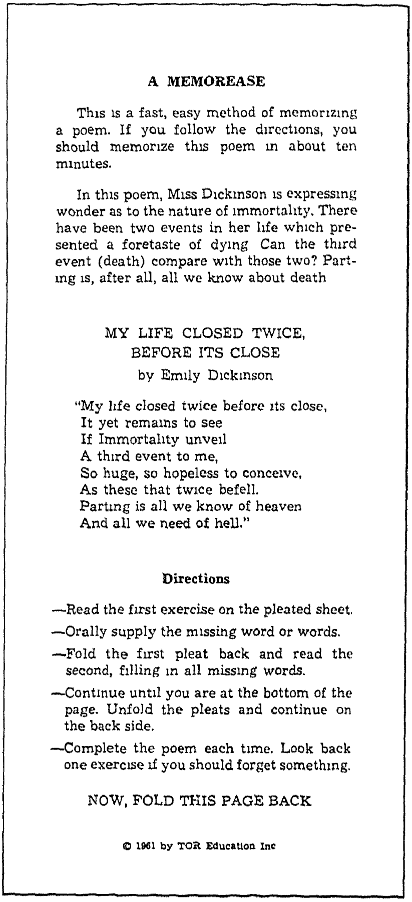

A MEMOREASE

This is a fast, easy method of memorizing a poem. If you follow the directions, you should memorize this poem in about ten minutes.

In this poem, Miss Dickinson is expressing wonder as to the nature of immortality. There have been two events in her life which presented a foretaste of dying Can the third event (death) compare with those two? Parting is, after all, all we know about death

MY LIFE CLOSED TWICE, BEFORE ITS CLOSE

by Emily Dickinson

"My life closed twice before its close,
It yet remains to see
If Immortality unveil
A third event to me,
So huge, so hopeless to conceive,
As these that twice befell.
Parting is all we know of heaven
And all we need of hell."

Directions

—Read the first exercise on the pleated sheet.

—Orally supply the missing word or words.

—Fold the first pleat back and read the second, filling in all missing words.

—Continue until you are at the bottom of the page. Unfold the pleats and continue on the back side.

—Complete the poem each time. Look back one exercise if you should forget something.

NOW, FOLD THIS PAGE BACK

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So huge, so hopeless to conceive, As these that twice befell Parting is all we know of heaven And all we need of ____.	My life closed twice before its close; It yet remains to see If Immortality ____ A ____ ____ to me, ____ ____, ____ hopeless ____ ____, ____ ____ that ____ ____.
So huge, so hopeless to conceive, As these that twice befell Parting is all ____ ____ ____ ____ ____ And all ____ ____ ____ ____	My life closed twice before its ____; It yet ____ to see If Immortality ____ ____ ____ ____ ____ ____, ____ ____, ____ ____ ____ ____, ____ ____ ____ ____ ____ . . . .
So huge, so hopeless to conceive, As these that twice ____ Parting ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____."	My life ____ twice ____ its ____; ____ yet ____ to see If Immortality ____ ____ ____ ____ ____ ____, ____ ____, ____ ____ ____ ____, ...
____ huge, so hopeless to ____, As ____ that twice ____. Parting ____ ____ ____ ____ ____ ____	My life ____ ____ ____ its ____; ____ yet ____ ____ ____ If ____ ____ ____ ____ ____ ____ ____, ...
If Immortality unveil A third event to me, ____ huge, so hopeless to ____, ____ ____ that ____ ____.	My ____ ____ ____ ____ ____ ____; ____ ____ ____ ____ ____ ____ ____ ____ . . . .
If Immortality unveil A third event to me, ____ huge, so hopeless to ____, ____ ____ that ____ ____.	My ____; . . . .
	____ . . . .

About the Editors . . .

Stuart Margulies is Director of the Automated Instructional Materials Corporation. He received his Ph.D. in Experimental Psychology from Columbia University in 1960 and has been a psychologist with the Naval Training Device Center and the Center for Programed Instruction. He has written and edited many programs and has published numerous articles on the use of programed instruction.

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